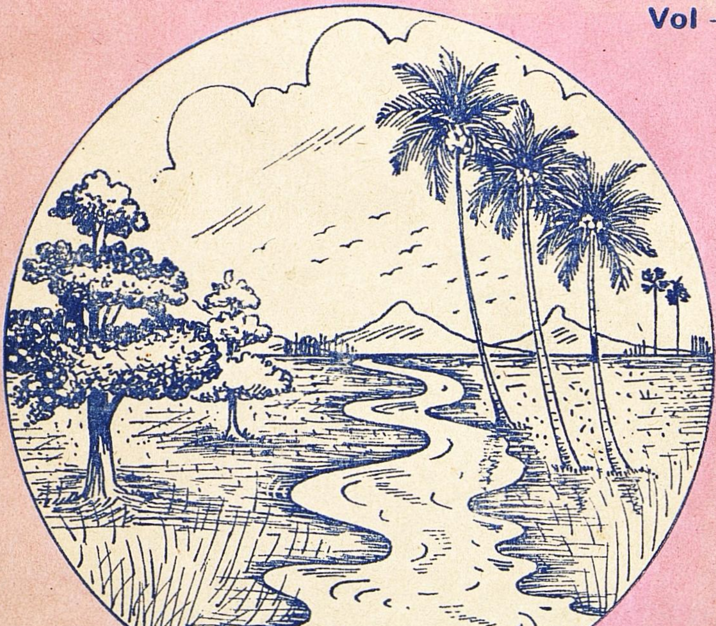
ENVIRONMENTAL STUDIES

HIGHER SECONDARY - FIRST YEAR

Vol — I



TAMILNADU TEXTBOOK SOCIETY

ENVIRONMENTAL STUDIES

Vol. I

HIGHER SECONDARY — FIRST YEAR

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Further Chapters will be continued in Vol. II

1. The Environment—An Introduction

Introduction

We live in an environment which consists of the four major elements water, air, land and living organisms such as plants and animals. Physical environment forms one group consisting of land, water and air. Organic or biological environment is another group consisting of plants and animals. The relatively narrow belt of living organisms - both the plant and animal life is called the biosphere.

The biosphere is a unique feature of the earth. All organisms in the biosphere are dependent on one another and each in turn depends on the physical environment of the area in which they live. The biosphere plays its part in various ways in the life of man. Thus it is essential both for the sustenance of life and march of human civilization.

The lithosphere or the surface of the earth is important from the point of view of the varied activities of man. The surface of the earth is used for the construction of buildings, roads, railways, etc. and for various economic activities such as manufacturing, farming and trade. The type of land use varies from one region to another depending upon the character of the land surface, for example the important agricultural regions of the world are the low lands below 100 meters in elevation. Steep slopes are unsuitable for settlement and economic activity. The earth surface besides being an important source of minerals and fuel, is also important for its soil cover.

The hydrosphere on the other hand includes the water bodies - oceans, lakes, rivers and other water bodies. The water bodies cover more than 75% of the earths surface. The oceans are the seat of incessent activities as it is the source of one of the most important food resource — fishes. The oceans modify the temperature of the air and supplies by far its greater part of water vapour. Apart from these, the oceans are used by man for navigation, thus bridging the distances separating the land masses.

The inland waters such as rivers, and lakes duplicate the values of the sea and add still some of their own. All these rivers, lakes and groundwater give man his most basic resource - his water supply for domestic, agricultural and industrial purposes. Apart from these, rivers are also harnessed by man for power generation, navigation, inland fishing and recreation.

The atmosphere is the air envelope which completely surrounds the earth (the hydrosphere and the lithosphere). The atmosphere acts as a blanket for the earth. The incoming short wave solar radiation and the outgoing long wave terres trial (earth) radiation is affected by it. The water vapour and carbon dioxide absorbed by the lower layers of the atmopshere keep the earth warm even at night. The differential heating of the atmosphere by the sun's rays brings about the atmospheric circulation leading to winds and rainfall. Plant and animal life are in harmony with the seasonal changes in weather. The temperature and rainfall also effect man to a great extent, for example, man uses more warm clothes to protect himself from the severety of low temperatures in winter. When the winter temperatures are extremely low, man consumes more calories to keep himself warm.

Concept of Environment

The concept of environment refers to the relationship between individual and its surroundings. The environment and the individual (organisms) are inseparable organisms dependent on the surroundings for satisfying their basic needs,

for living space, food and shelter. The great diversity we see in nature, is the result of different types of environments having varying elements of relief, drainage and climatic conditions These bring out variations in plant and animal life. The elements are landforms, climate, drainage, soils, flora (natural vegetation) and fauna (natural animal life).

All these elements are important because they have a bearing on man and his economic activities. All these constitute materials and forces, advantages and disadvantages, which must always be considered by man, as he develops the economic, social and political aspects of the society.

Man converts the natural environment into a cultural environment. The type of cultural or man made environment, thus depends on the elements of the natural environment surrounding him, his advancement in technology and science and his basic needs.

Cultural Environment

In an uninhabited region the natural environment alone is present, but when man invades the natural environment, he begins to adjust himself to it and commences active exploitation of one or more of the elements of the environment. They draw upon the natural resources for the materials with which to construct the cultural landscape. They capitalize upon those elements which help in promoting social solidarity and political safety. This is known as 'eccesis' or adjustment which consists of selection and adaptation.

By expending vast amount of labour and energy men transform the natural environment which becomes obscured or even unrecognisable after some time. They may dig minerals, fell trees, destroy wild game, harness the streams for power generation, navigation and irrigation and cover the surface with farms, towns, mills, factories etc. As a consequence areas develop into farming regions, regions of pasture and regions of manufacturing and commerce. Thus each region specialises in activities which help

in the utilization of the natural resources available in the local area. This leads to the areal specialisation of economic activity.

All human activity takes place in response primarily to the demand for the satisfaction of human needs and desires and not in response to the controlling influence of the environment. This demand is to satisfy the need for food, shelter and clothing. Over and above these more elementary wants, a whole range of other desires and needs of a less urgent type, such as the demand for political institutions, recreational facilities and the satisfaction of the aesthetic sense have also to be satisfied. Thus the satisfaction of demand is the driving force behind all production and the performance of services whether they be undertaken to provide food or clothing or shelter. Thus while engaging in his activities man utilizes and modifies his natural environment and is in turn modified by it. This double process is the actual process of adaptation.

In this view the geography of any area presents a three fold aspect. On the one side we have a human group activity engaged in the process of satisfying human wants. On the other hand the natural environment of land forms, rock structure, climate, vegetation and animal life provide the stage for human activity. Between the two and acting as the central core of the tripartite division is the relationship between the activity of the community and their natural habitat ; such relationship being dependent on man's effort to modify the environment to satisfy his needs, and the effort as it were, of the environment to modify and limit his modes of doing so.

Man's struggle to adapt the natural environment to his needs is deeply engraven on the environment. The concrete expression of the process of adaptation takes the form of the cultural as opposed to the natural landscape ; in other words, the natural landscape as modified by man. It is the concrete expression of a double process, man's effort to mould nature to his will, and nature's modification of what would otherwise be man's unrestricted activity.

The effects of the double process is well seen in such an element of the cultural landscape as a railway track. When man in response to the demand for transportation between centres, constructs a railway line, he modifies the natural landscape by making a level road bed and laying on it lines of rail. He adds many other features, such as stations, signal lines, signal posts, level crossings - all of which are necessary, irrespective of the nature of the topography. He thus introduces into the natural landscape elements which were not there before, and to that extent may be considered as having modified the natural landscape in response to the demand for transportation facilities. To the extent that in satisfying the demand for these railway facilities man departs from the level, straight line track between two points, to tunnel, makes cuttings, embankments, or introduces other modification such as change of direction, his activity is being modified by nature. Thus man's activity modifies the face of nature and is in turn modified by nature. The objective expression of all this is the railway track as modified, with the cuttings, embankments, tunnels etc. forming a prominent unit of the cultural landscape.

In similar fashion we can think of man's various forms of shelter, his houses, factories, warehouses, shops and offices, as the expression of his endeavour to adapt nature to his need for shelter, or in other words as the expression of his adjustment to nature in attempting to satisfy the demand for shelter or the need for shelter. His fields and growing crops, his houses and fences, express his striving to adapt to his environment to satisfy the needs for food and raw materials. His coal dumps, represent an environmental adjustment to the need for power and warmth; his roads, railways, waterways, and terminal facilities fulfil his need for transport and social unification; his community halls and police stations express his need for community organisation for administrative purposes and the maintenance of law and order and many other things. Throughout all this is man himself, at work or at play, moving, standing, or sitting an essential element of the cultural landscape, and the motivating force of it all in the effort to satisfy his needs.

Since the objects forming the cultural landscape vary in character, shape, size and distribution, both with the activities of the community and the nature of the environment, the cultural landscape is the best available objective expression of relationship between human activity and natural environmental conditions.

E. H. Haeckel (1834-1919), the German naturalist, is the originator of the term 'ecology' and defines it as the relationship between all organisms living together in one and the same locality and their adaptation to the environment. Basic therefore is the relationship between man and environment, in the view that every area with a particular relief, location and climate is a composite environment, united by a common bond of adaptation to the environment.

Environment as an Ecosystem

Plants and animals together with the natural environment with which they interact is an 'ecosystem'. The term ecosystem is a contraction of ecological systems and these are the systems which include both organisms and their physical environment. Man is a member of this ecosystem and his food resources are derived from this ecosystem.

All organisms in the ecosystem need food as a source of energy and for their growth. Based on the food habits, organisms can be grouped into three major divisions—producers, consumers and decomposers.

Let us take the carbon cycle as an example. The main source of carbon is provided by the earth's lower atmosphere, where carbon-dioxide forms 0.033% of the total volume. Climatically carbon-dioxide is important as a heat absorbing blanket helping to regulate the air temperatures near the earth's surface; biologically carbon-dioxide is essential for plant growth. Green plants with the pigments chlorophyll combine carbon dioxide and water through photosynthesis (meaning putting together, with light, in Greek) to produce the food materials necessary for life. Photosynthesis is activated by solar radiation,

Green plants may be considered as basic producers in the carbon cycle, because they manufacture consumable energy (carbohydrates) from atmospheric carbon and solar energy.

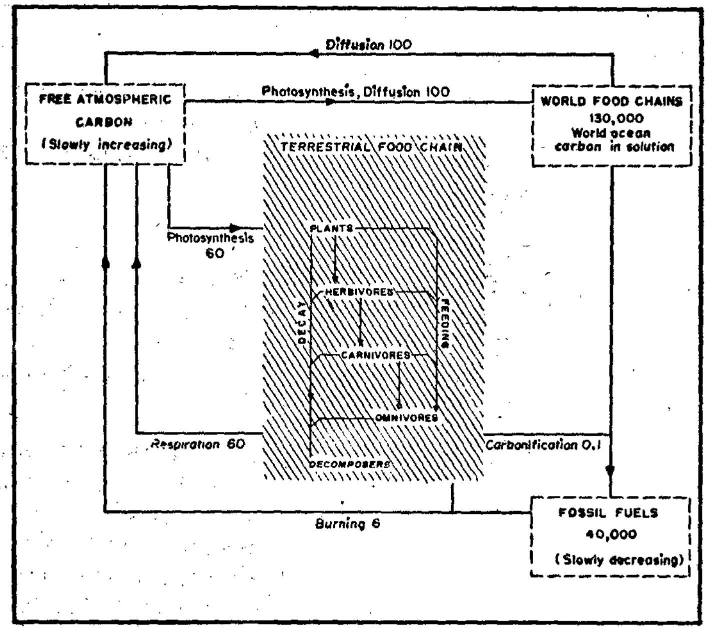


Fig. 1.1. Carbon Cycle and World Carbon Balance

The carbon cycle is completed and carbon-dioxide is returned to the atmosphere as seen in figure 1-1.

The consumers are those which are not able to produce their own food and therefore are dependent on the other organisms. For example, the food produced by land plants are eaten by animals here termed as consumers; and the energy stored in the food sustains their activity. Some of the carbon is stored in the body and the rest excreted by respiration as carbondioxide.

Consumers can be divided into **herbivores, carnivores** or omnivores depending on whether their diet is wholly plants, wholly animals or a mixture of the two (as with man).

The final role in the carbon cycle is played by decomposers and these consist of bacteria and fungi that breakdown the carbon stored in the tissues, of dead plants and animals. In the decomposition process carbon is again returned to the atmosphere or the soil.

The carbon cycle is an example of the ecosystem and includes biological elements (producers, consumers and decomposers), as well as inorganic elements - the atmosphere and carbon store in fossil fuels.

Environmental Contrasts

The earth is the home of man. The earth exerts a far reaching and fundamental influence on the patterns of human activity. The available land resources affect the economic life because the production of raw material is dependent on the nature of the land.

The major types of land resources are the mountains, plains, plateaus and hills, of these the mountains are the least hospitable to human culture. The main occupations of the people in the mountains are grazing of domestic animals, digging minerals if any or lumbering. The mountain ranges like the lofty Himalayas are a hindrance to communication and therefore trade and commerce, industry and other economic activities which are directly dependent on communication facilities are absent here. On the other hand some of the areas in the mountain region provide facilities for the construction of summer resorts, e.g. Kodaikanal and Ootacamund in Tamilnadu. Some of the important hill stations in the Himalayas are Dhera Dun, Darjeeling. Nainital, Simla, Khatmandu, etc. These hill resorts are the most important centres of tourist attraction.

In contrast to the mountains are the plains with less than 100 m. above sea level. These include the Indus and Ganges basins and the coastal low lands of India. These regions are the most thickly populated regions in India mainly because of the level land, abundance of water from rainfall and perennial rivers, good alluvial soils and predominantly agricultural economy.

Contrasts in the cultural landscape are also found between the arid Rajasthan desert and the moist regions of the lower Ganges basin. In the former the most important crops grown are the millets like Bajra while in the lower Ganges basin, due to the alluvial soils and high rainfall, rice and jute form the most important crops. So we see here, how contrasting relief and climatic elements give rise to contrasting cultural landscapes. These environmental contrasts are also well noticeable between the perennial and non-perennial streams. It is only the perennial streams that are harnessed for power generation, navigation, irrigation, fishing, recreation etc., while the non-perennial streams do not permit man to develop a cultural landscape of similar magnitude. Thus man's adaptation to nature has led to the development of cities on sites such as Bombay, Calcutta and Madras which are important sea ports which command a resourceful hinterland. In contrast to these are the hundreds of villages whose activities are directed towards the cultivation of land as in the Ganges basin. Similar contrasts are also found between the Damodar valley which are studded with coal fields where mining is an important activity and the vale of Kashmir where sheep rearing and fruit culture are important due to the climate which is conducive for these activities.

Man and Environment Relations

The development of geographical ideas from the early Greek view of geography is a description of the earth; to the modern conception of human geography, it is a study of the adaptation of nature or natural environment by man, in the process of satisfying his desires.

It is possible to study the way in which specific human groups or communities have adjusted themselves to and modified the natural conditions in which they live. The study of this adjustment is what is called human ecology.

One view is that man has adjusted himself to nature; while the other is that man has adapted nature in the effort to satisfy his needs. It appears more and more that man has

adapted nature rather than adjusted himself and his activities to nature.

In human geography we seek to examine those facts of geography which relate directly to man and his activities observing both their effects upon him and the results of his own impact on his surroundings. It soon becomes apparent that such geographical facts and their effects on man are virtually innumerable, and they are inter-woven with man's activities in a great variety of ways.

To understand the relationship between man and the region in which he lives, we should properly take into account every single part of his environment; for if one single element is altered in any way, it may set up a chain of events which will ultimately affect all the others.

Consider, for instance, the possible consequences of deforestation. An indiscriminate destruction of forest cover by lumbering without subsequent afforestation has taken place in many parts of the world. This has produced striking results and repercussions which have been far more widespread. The lack of protective vegetation means that the ground becomes exposed to wind and rain. The rain water now runs off the land surfaces more quickly. As vegetation cover is absent there is rapid evaporation and the result may be that, not enough water seeps into the ground, to charge the water table, plants other than the deep rooted ones, may perish, and the animals which feed on them migrate. The lowering of the water table will also have an adverse effect on the water supply to settlements either for industrial, domestic or other uses. Link by link the chain of effects may extend throughout the region.

Even in a small area, so many factors must be considered that only by making a piecemeal study of very many environmental elements or of groups of elements, is it possible ultimately, to obtain a broad view of the overall effect of environment upon man, or to predict the possible consequence of certain action on the part of man.

Man is the central figure and therefore, perhaps, we should first observe the facts of his occupation of the earth's surface-how and where he lives. It is convenient first to draw attention to the ways in which various natural phenomena affect mankind. These do not affect man singly but as part of his general environment, and although countless others have some influence, however remote, upon his activities we cannot hope even to list, let alone appreciate them all.

EXERCISE—1

Short Answer Questions:

1. Define the concept of environment.
2. What is a cultural environment?
3. What do you mean by the term ecosystem?
4. Explain the carbon cycle.
5. Give example for herbivores consumers and carnivores consumers.
6. What are the major types of land resources?

Essay Questions:

1. With suitable examples, explain how man converts the natural environment into cultural environment.
2. Discuss the various aspects of environmental contrasts.
3. Bring out the relationship between man and environment.

2. Dynamic Environment

In the foregoing chapter we have explained the concept of environment. Now, it is clear that environment cannot be effectively studied entirely by itself, without any reference to living organisms. Thus, we go a step further in establishing a fact that the functional relationship between environment and man is very complex one. In order to understand this functional relationship we have to identify the different standpoints with regard to environment and explain the fact that environment is dynamic in nature. In general the environment can be viewed through the following four categories (i) the physical environment (climate, geology, structure and soil conditions) (ii) the living environment of plants and animals dependent in turn on the physical environment (iii) the social environment (man's fellow men) and (iv) the intimate physico-chemical environment and so called internal enviroment.

With this background, let us understand the dynamic nature of environment. None of the factors in the above said categories are static. For example, the rainfall results in the erosion of land by streams, thereby changing the landform of a particular area. This brings a chain of changes in the growth of plants and the existence of animal life. It is also possible to think that changes are brought about by several factors. These factors can be studied under internal and external processes. Let us consider the internal factors. The internal factors are diastrophic in nature, namely earth movements both vertical and horizontal and volcanoes and earthquakes etc. If we take the case of a volcano, we understand that material erupted accumulates around the vent to form a low hill. Similarly when earthquakes originate near the coast huge tidal waves invade the coast causing temporary or permanent submergence of land. The external factors are rainfall, temperature, flow of rivers, movement of winds, movement of ice

and waves etc. These factors modify the surface of the ground. Such modifications affect the habitat of the living organisms. For example, the wave erosion on the shore produces cliffs. The waves break at the foot of the cliffs resulting in the recession of cliffs and deposition of material. This may act as an abode to different type of marine organisms and plants.

In addition to these factors, we also note the interaction between the different elements of environment. For example, let us take the Nilagiri Hills in Tamilnadu. The river Bhavani flows from the hills and joins river Cauvery in the Coimbatore District. Let us say in one season there is a sudden increase in the amount of rainfall (which is a component of climatic element) and this will result in floods, erosion of land, submergence of fertile cultivated land. Further there may be damage to crops, human life, and animal life etc. We see a chain of reactions due to the interaction of different elements such as climate, land, plant and animal life given within an environmental set up. In other words we see that the entire system in the environment is affected. This system is popularly known as ecosystem.

Ecosystem

An individual plant or animal cannot exist as an isolated entity. It is dependent upon its environment including other organisms to which it relates. Thus plants and animals occurring together, plus that part of their physical environment with which they interact, constitute an "**Ecosystem**". This system is nearly self-contained. The subject matter of the ecology of natural systems, deals with (a) the dynamics of the flow of energy and materials in a given environment and (b) adaptation made by the individual and the species to find a place within the environment.

Concept of system and system analysis

Once we introduce the term ecosystem, it is needless to say that we have to understand the concept of system and system analysis. Let us see what is a system ?

System has not only a specific scientific meaning but also has become the focus of a new "interdisciplinary discipline" known as general system theory. However, one of the widely quoted general definition of a system is that it is "a set of objects together with the relationships between the objects and their attributes". The objects of the ecosystem are plant, animal and environment. The relationships between the objects are the connections that tie the system together. This is a crucial component of all systems. The analysis of a system is useful because it emphasizes wholeness and interdependence among the components of a system. A second advantage of the system concept is that it applies at all levels of analysis from the microscale to the macroscale and to all kinds of phenomena, "from atomic particles, through atoms molecules, crystals, viruses, cells, organs, individuals, plants, animals, groups, societies, planets and galaxies".

Abiotic and Biotic Elements in the Ecosystem

We have established the need for understanding the ecosystem in analysing the concept of environment. Now let us understand the abiotic and biotic elements in detail. For this, let us divide the environment into two broad categories. (i) abiotic environment and (2) biotic environment. The abiotic environment covers lithosphere, atmosphere and hydrosphere whereas the biotic environment includes the biosphere. Of course it is not possible to separate these two environments, because functionally they are interrelated. In this section let us analyse the basic characteristic features of abiotic and biotic components in the ecosystem.

Abiotic Environment

The abiotic environmental substances are non living in nature and they include basic inorganic elements and compounds such as water and carbondioxide, calcium and oxygen, carbonates and phosphates and an array of products produced by the decay of dead plants and animal tissues. They also include such physical factors and gradients as moisture, winds, currents, and solar radiation. Thus the ecological relationships are manifested not in a vacum but in a physico - chemical

settings, sets of non-living or abiotic environmental substances as indicated above.

Each of the three elements mentioned earlier viz. lithosphere, atmosphere and hydrosphere of the abiotic environment, has specific properties and rates of change. These changes can be grouped under long-term changes and short-term changes. In the case of lithosphere, where we deal with earth surface, the long- term changes can be identified through several examples such as the origin and growth of the Himalayan Mountains in the tertiary period, the formation of Western Ghats, Indo-gangetic plain and the formation of Deccan Lava plateau etc. The short-term changes can be illustrated in the following manner.

The alternation of darkness and light caused by the rotation of earth brings in differences in the distribution of solar energy. Thus the night time is a period of energy loss by radiation from the land surface and falling temperatures. From dawn onwards, the average amount of incoming solar energy increases; it reaches a noon-time peak, then declines again as evening approaches. Now such an alternative change affects the different type of rocks in various intensities resulting in the disintegration of rocks. Thus we are able to see the changes in the lithosphere both from long and short term point of view. Similarly in the case of atmosphere, the long-term changes are recognised as climatic changes.

For example, the earth's climate which had been cooling slowly for the last 65 million years, grew much colder about 2 million years ago. The effect was more as the world's water was locked up in the form of ice. This led to the general expansion of polar ice sheets which extend over the northern parts of North America and Eurasia. Further the return flow to the oceans lessened and consequently the sea level fell. It is estimated that the ice caps lowered the ocean level by approximately 100 - 125 mm. In addition to this, the broad climatic and vegetational belts shifted towards the equator. For example, the Sahara Desert in North Africa may have moved as far south as latitude 10°-15° N. Again almost 10,000 years ago, the poleward shifts of climatic zones began. The ice caps contracted. Thus, a dynamic change is always noticed

in both the atmosphere and hydrosphere. The evidences of climatic changes in the last 2000 years have also been noticed. A low point in temperature was reached in the northern hemisphere in the middle of the eighteenth century and temperatures remained low in the nineteenth century. As regards the short -term changes, on some summer days, we can observe the daily build up of cloud formation. The hydrosphere records the long -term changes in the form of sea level fluctuation as indicated above. The short-term round abouts can be observed in the difference between high tide level and low tide level each and every day.

So far we have discussed the changes that take place in the three important components of abiotic environment. Now let us discuss the interaction between more than one element in the abiotic environment. This can be illustrated from the following example. Very high temperature over the sea results in evaporation of water, which in turn passes through the process of cloud formation, condensation and precipitation. After the rainfall, the run off is noticed in the form of rivers and thus ultimately rainfall interacts with land. Once again the fresh water joins the sea thereby reducing the salinity of that particular area. Incidentally, sediments brought from the surface of the land are also deposited in the same area. The above said process clearly indicates the interaction between various elements in the physical environment.

Biotic Environment

The biotic environment is mainly concerned with the biosphere. The main biotic components are plants, animals and microbes. These components interact with each other, and bring about changes in the biosphere. Finally these biotic components interact with abiotic components resulting in a greater change. The whole system can be recognised as ecological system or ecosystem, the concept which we have established in the earlier section of this chapter. In this section let us study this complicated interaction among various elements and the resulting phenomena. Before we analyse the interaction and change, it is necessary to understand the concept of kinship.

Energy Oriented System, Mineral and Nutrient Analysis

In the ecosystem, ecological kinship is demonstrated. The kinship analysis is energy oriented. In other words radiant energy, in the form of sunlight is the significant source of energy for any ecosystem. This energy is mainly used in the photosynthetic process, whereby carbondioxide is converted into energy rich carbon compounds. The term " producers " is normally used to the organisms that perform the vital function. For example, we have the algae of a pond, the grass of a field and the trees of the forest. The chemosynthetic bacteria are also producers but play a less significant role in the energy relations of an ecosystem. This bacteria plays an important-role in the movement of mineral nutrients in the ecosystems. Ultimately the energy incorporated in the producers, helps in the producer's own growth and metabolism. Thus we have two types of organisms (a) autotrophic (self feeding) and (b) heterotrophic (other feeding) — organisms, whose nutritional needs are met by feeding on other organisms. A primary consumer is a herbivorous feeding on the producer. The secondary consumer feeds on the primary consumer. A primary consumer or more commonly, a herbivore, or secondary consumer, is a heterotroph deriving its energy indirectly from the producer by way of the herbivore. We have also carnivores that feed on other carnivores. The reindeer moss-reindeer human food chain in Lapland can be cited as the best example for the autotroph - heterotroph relationship. Here the reindeer feed on moss and lichen. The moss and lichens convert carbondioxide into carbohydrates. Thus these are the primary producers. These primary producers are eaten by the primary consumers that is, the reindeers. Man, being the secondary consumer, feed on the reindeers. This is also a good example for the changes that are brought about by the interaction of elements in the biotic environment. In short we could say that this autotroph, heterotroph, producer - consumer, or producer-herbivore - carnivore relationship is the direction of energy movement through the ecosystem. This is unidirectional and non-cyclic. Thus we could clearly state that one way flow of energy constitutes one of the most important principles of the ecosystem.

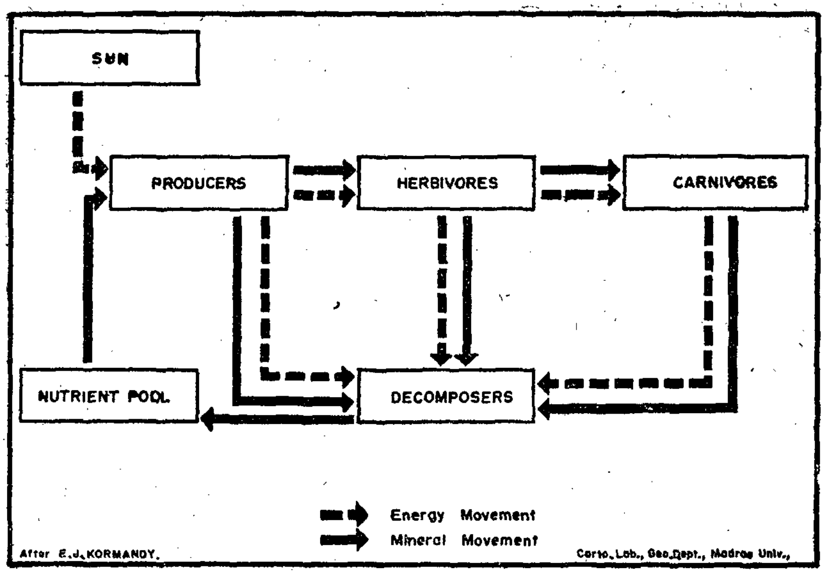


Fig. 2.1

A Simplified Model of Energy and Mineral Movement in Ecosystems

{ The energy movement or flow is noncyclic. The nutrient movement is cyclic. }

In this context, it may be pointed out that there is another group of heterotrophs in ecosystems known as "decomposers". They consist of bacteria and fungi and perform an invaluable service to the ecosystem, the mineralisation of organic matter. They perform such an activity by which the basic elements found in protoplasm are related to the environment. This will be made available for reuse by producers. Now this process of decomposer i. e. the movements of nutrients is cyclic. The following simplified model shows the energy and mineral movement in ecosystems.

This model will clearly indicate the fact that energy flow is non-cyclic, whereas nutrient movement is cyclic. However, it may be pointed out that two ecological processes of energy flow and mineral cycling involving the interaction between the physico-chemical environment and the biotic assemblage, lie at the head of ecosystem dynamics.

Generalised Model of Energy Flow

So far we have discussed how far energy flow plays an important role in the ecosystem. No doubt, the energy flow varies from one system to another. However, the variation can be noted only in the form of inputs and fates of energy.

In the above cited diagram, it is assumed that there will be equal flow of energy from two primary sources, i.e. (a) imported living and dead organic matter and (b) photo-synthesis. It is also assumed that the contribution from each in the rest of the chain to be about equal.

It can also be pointed out that type of information required to construct an energy flow diagram for any particular ecosystem is extremely difficult to come by. This is mainly because of the fact that one has to study simultaneously numerous variables inherent in the material being studied. For example, young trees undergo photosynthesis at a rate different from old trees. Similarly the young as well as smaller animals metabolize at a higher rates than older and larger ones. Further one has to take into account seasonal shifts in quality and amount of sunlight. However, in laboratory, these systems, are

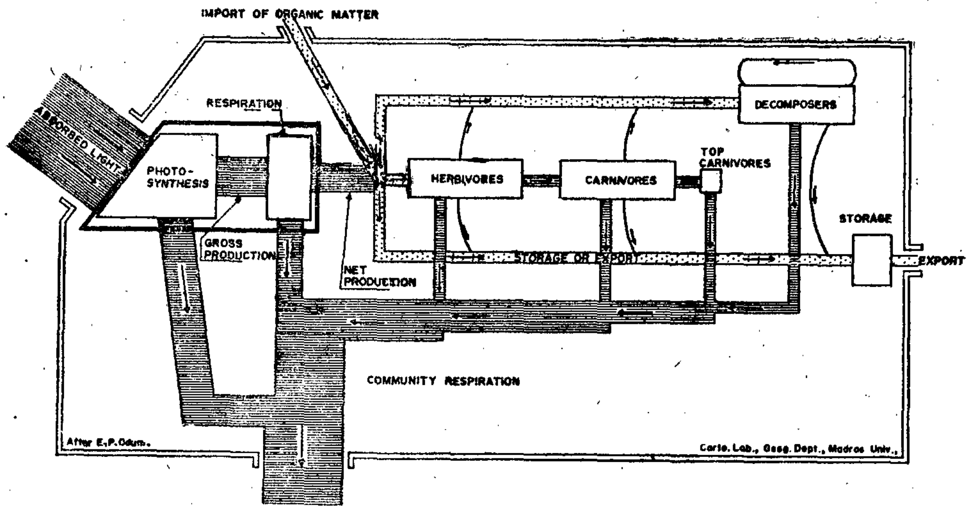


Fig. 2.2

Generalised Model of Energy Flow

studied very carefully and in the model the term "gross ecological efficiency" is used to indicate the transfer of energy flow from one trophic level to the next. This energy flow will be more clear when we understand the concept of food chain.

Food Chain

It is a known fact that all animals get their food from plants, either directly or indirectly by feeding on other animals that feed on plants. Both the process of photosynthesis and animal cycles provide the basis of lengthy food chains. To explain this phenomena let us take the fish like tuna that are caught from the oceans. Here the phytoplankton are consumed by larvae and shrimps. They are in turn eaten by squids and small fish, which form part of the food consumed by Tuna. It is estimated that in each case it takes from 5 to 10 food units (calories) of the prey to produce one unit of the predator. This difference is termed as **food conversion ratio.** Thus one unit of tuna consumed by man represents an estimated 5000 units of phytoplankton. It is possible to illustrate the levels in a food chain in the form of a food pyramid. In this type of pyramid, each step is known as trophic level. The term trophe means food in Greek. Now let us analyse the various levels of the pyramid from the base. The base level represents the green vegetation with energy contained in the plant tissues. The next level (level -2) consists of herbivores animals that feed on the plants. The third level of carnivorous animals that feed on herbivorous animals. The fourth level, which is the last but one represents carnivorous animals and all the lower levels. The last level, which occupies the top level includes decomposers that breakdown the dead tissues of organisms at all other levels of the food chain.

Further, the changes that are found in the number of organisms over the globe can also be represented in the form of a pyramid. For example at the lowest level of the pyramid large number of small organisms could be supported on a given area. Because, they are all capable of producing their own food. At the next trophic level, of primary consumers, the number of organisms that could be supported has to be necessarily smaller because each consumer feeds on a number

of producers at the lower level. At the next trophic level of secondary consumers, their number is less than that of primary consumers. Thus a pyramid of numbers comes into existence. Man may considered to be at the top of the pyramid. Again, when we look into the spatial distribution of organisms we see the same "pyramidal character". In other words the small organisms like pests, worms, insects etc. which live on smaller producers live in a much smaller space. Whereas the slightly bigger animals like squirrels etc. move over large areas for their food. Now bigger animals, like tiger, and elephants certainly have the chance of moving over much larger areas than the squirrels in search of food. Here again, man occupying the top level of the pyramid, is able to draw the food and his requirements from all over the world.

Changes in the Biological Environment

So far we have discussed the various relationships that exists in the ecosystems. The following example will give an idea how changes are brought about in a biological environment. Let us take the corals. We know that these corals are minute marine animals. They live in huge colonies in shallow tropical seas, observed in the form of reefs and atolls. We have very good examples of coral reefs along the Ramanathapuram Coast and in the Rameswaram island in Tamil Nadu. In fact Rameswaram island is a good example of coral island formed by the organisms. It is found that these minute organisms secrete calcium carbonate to form coral reefs. These organisms are very sensitive to the depth of water. Thus, when the depth decreases, sunlight becomes more abundant, consequently the rate of growth of the reefs increases. This accelerated growth further decreases the depth of the water, increases the light, accelerates the growth of algae and so on. This type of relationship is known as positive feed back. This positive feed back shows the change that is brought about in the biological environment.

Again when the reefs grow above the sea level, the waves come, attack the reef and thereby a check is brought in the growth pattern. This type of effect is known as negative feed back, which limits the growth. This example can also be

applied to the animal world in the biological environment. The following diagram helps to understand the feed back loops in a system.

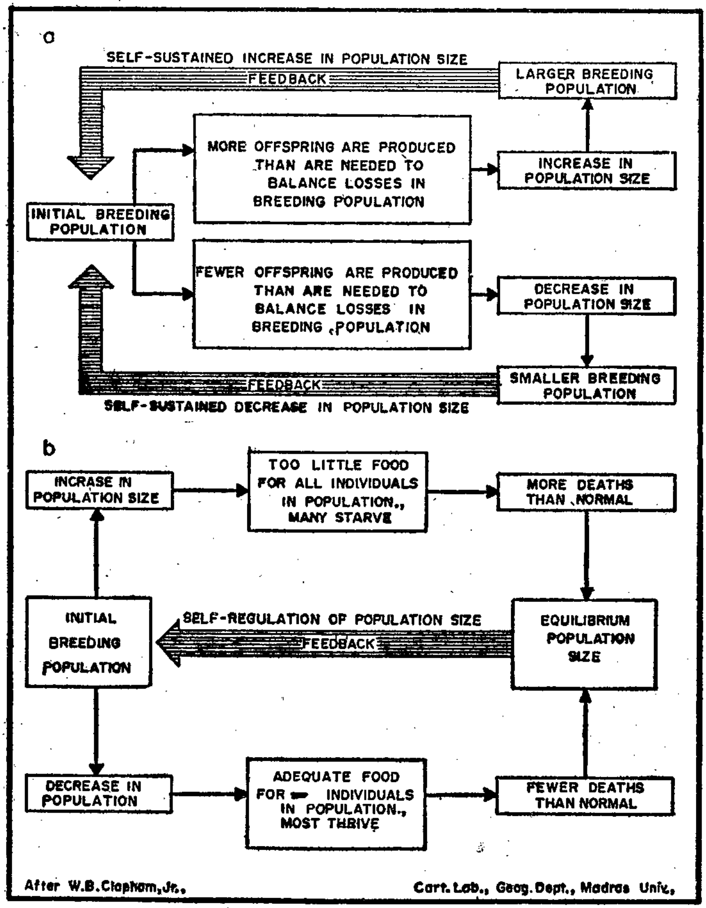


Fig 2.3

Feed Back System

(a) Positive feed backs – Changes that are self sustaining

(b) Negative feed backs – Self regulation

The diagrams show that feed back starts with initial breeding of population. The positive feed back leads to unstable outcomes. For example, the animal population either declines or explodes. In the second diagram, the situation is stable and the number of deaths are controlled by the food supply. The above said concept can be explained in the following manner. First let us take the simplest life of community interaction, which can be identified as a chain reaction.

Cats eat rats, rats attack beehives, bees polinate flowers and produce honey. Thus the population of wild flowers, and the price of honey, is partly dependent on the population of cats. So one could see the reverberations, large or small, beneficial or harmful throughout the system. Interactions, between diverse species are found to promote stable ecosystems.

Let us take the case of the species of grazersbison, elks and moose on the ecological balance of an area. Moose eat sapplings and small bushes. With bush growth held in check, grasses find room to grow. Bison eat grass. The elks eat either leaves or grasses. Thus the community of grazers acts on the community of plants to ensure that an equilibrium status quo is maintained.

There is another good example to explain the role of plants in relation to changing weather. In the prarie region both annual and perennial grasses grow. The former has shorter and less extensive roots whereas the latter have deep roots. We have little water during the dry years. During this period, the perennials which use water deep underground, are able to live. By such an action they hold the soil and protect it from blowing away by dry summer winds. In years of high rainfall, the annuals sprout quickly, fill in bare spots and with their excessive surface root systems prevent soil erosion from runoff. This shows the changing characteristic features of the biological environment. From the above said analysis it is clear that changes occur at all levels i. e. both in the abiotic and biotic environments. And these changes are dynamic.

Properties of Ecosystems

The significant properties of ecosystems are energy flow, nutrient cycling and population self regulation. However, none of the ecological processes occur in isolation. Each is manifested by particular assemblage of different species of populations in particular physico-chemical environments.

Variation of Ecosystem

Does the ecosystems differ widely? Yes. It differs with respect to size, location, weather patterns and the type of animals and plants. For example a watershed in Western Ghats, Thar desert in Rajasthan, Lake Manosarovar in the Himalayas are all distinct ecosystems. However, we see a set of common processes in all these places. In each ecosystem we have plants which use energy from the sun to convert simple chemicals from the environment into complex, energy-rich tissues. Similarly we have various forms of plant-eaters, predators who eat the plant eaters, predators who eat the predators and organisms that cause decay. In spite of the fact that ecosystems are geographically distinct areas, with unique characteristics, they are interconnected.

Major Ecosystems of the Earth

The major ecosystems are (a) ocean systems (b) estuary systems (c) freshwater systems and (d) terrestrial systems.

(a) Ocean Systems

This area holds a varied and interwoven set of ecosystems. The euphotic zone, known as illuminated section where photosynthesis takes place varies from place to place. For example, though the depth of the photosynthetic zone is greatest in the open ocean, the rate of photosynthesis is low because of low concentration of plant nutrients. In areas near shore, various species of algae, commonly known as sea-weed, are abundant and account for a significant portion of the net production of living matter.

(b) Estuary Systems

The relationships in this system are similar to that of ocean water. The only difference is that there are more trophic

levels in salt water than in fresh water. Further the continuous fertilization of this system is carried out by nutrients leached from near by soil.

(c) Fresh Water Systems

Ponds, lakes, springs, creeks and rivers all have unique and characteristic species.

(d) Terrestrial Systems

These are commonly known as biomes. This results due to the interactions of many environmental, biological, and evolutionary factors. Rainfall, average and seasonal temparature, altitude and soil conditions all have profound influences. We have regions like Prairie, Desert areas, Mountain areas (like Himalayas, Andies etc.) and Tundra etc. in this category.

Natural Succession

This is defined as the sequence of changes through which an ecosystem passes as time goes on. The climax is known as the final stage that is "unchanging". Such climax has a composition which in turn depends on physical environment. As succession continues, changes occur not only in the terrain and types of species present, but also in the trophic structure of the system. For instance the climax structure is the type of system that has produced things of beauty - the evergreen forests, the Gangetic plains etc. If we take climax vegetation as an example we will be able to explain the succession in a better manner. For instance we say that an area has reached climax vegetation when we see a perfect balance between the growth of various species of plants and the environment in the natural process. But man's interference can be noticed either before the claimax is reached or even before the proper growth of several species. Such areas are common in the present world. There are very few areas where we have climax vegetation, without the interference of man. Climax systems are often determined in large part by seasonal variations and geological cycles.

The Influence of man on biosphere

Man occupies an important position in the flow of energy through the biosphere. He must necessarily interact with thous-

ands of other species of plants and animals. Inspite of this why do we consider humans separately. This is mainly because of the fact that man has unprecedented power at his disposal. With his ability to increase the productivity or destroy the ecosystems of the earth he plays an important role. It is observed that man has been very successful at reducing the competition from other species. This is clear from the increase of human population in a short span of time as compared with that of geological time scale. It is mainly because man's social and technological changes are orders of magnitude faster than evolution.

Let us take the case of North America. Today, we see that some of the native ecosystems, such as the tall grass prairie and eastern hard wood forests are altered almost beyond recognition. Even when we look at the animals beyond, we see large predators like tigers and lions have been pushed into a few remote areas. In fact we find some of the species are fastly disappearing from the scene. In place of the natural forest and ranges, millions of acres of intensively cultivated land produce large yields of food stuffs to feed millions of people. It is also a known fact that man has introduced into environment the radio active forms of nutrients and of toxic substances such as detergents and pesticides. This has to be incorporated into man-oriented food chains and as a consequence of this man faces a major problem today.

Population Systems

So far we have discussed the various changes that we found in the ecosystem. We have also seen from the earlier sections that it is very difficult to include population system within the ecosystem, because of the peculiar character of man. Like the ecosystem, even the population system is dynamic. It is established that not only the total population will increase, but also the rate of growth; the acceleration, will probably continue its current rapid ascent. By 1970, the world population was approximately 3.5 billion persons. The increase in world population from 1950 to 1970 was about twice the size of the world population in 1650. Such a dynamic change in population will definitely have an impact on the environment.

Impact on Physical Environment

The last 200 years of human activity have used up materials of the earth accumulated by 2 billion years of natural processes. The increased use of resources, lead to the depletion of resources resulting in the spatial pattern of changes of economic development in the world. First let us take crowding. Allowing approximately one square yard of land per person and taking one of the more pessimistic and therefore larger projections of world population growth, estimates show that the last available land will be used up on Friday, November 13, 2104. Of course this is not a correct argument. But it does show the danger of overcrowding on the land. More and more area will be exploited, utilised, resulting in a series of problems like erosion, land sliding, droughts and floods. Noise, heat, waste and trash all create problems, when brought together at nearly unbearable concentrations in cities.

The continuous and rapid expansion in volume and growing intensity and radical transformation of industrial production, first of all, strengthens the following major influences on the natural environment.

a) increase in volume of consumption, as well as an enlargement in the range of natural resources used.

b) increase in volume and enlargement of the variety of industrial waste.

c) increase in waste, anthropogenic energy (mostly of heat) dissipated into the surrounding environment.

The latest technological progress in transport and in particular, the exceedingly rapid growth in automobiles, as well as air transport have important and well known consequences. First and foremost, it leads to the irrepressible growth of air pollution and noise levels.

Impact on Biotic Environment

Let us take a simple example of urban sewage disposal to a lake. This action brings the nutrients in deadly con-

centrations to larger bodies of water. The result is eutrephication in the form of increasing production of algae. This, in turn, reduces the gaseous content of the water, suffocates fish and generally adds to the unpleasant conditions which threaten to destroy the fish. Sometimes an animal or a plant can simply be over harvested to the point where it can no longer maintain itself. Whales and redwood trees face this fate unless effective and protective action is taken soon.

Removal of species from the ecosystem allows some other plant or animal which was originally held in check by it to experience a population explosion, that is over production. The following example from Sabah in Malaysia will give an idea about the complexities of extinction and over production and the role of man. In 1956, the coco production was introduced. Man cleared large tracts of forests. Then the valuable commercial timber was destroyed. The remainder of the forest was either burnt, or cut and left to rot, or allowed to stand as shade for the coco seedlings. The net result is that the coco plantations exist as islands surrounded by secondary growth with the original forest just beyond.

Now the disrupted territory at an edge of the forest acted as an ideal environment for fugitive and volunteer plant species. It should be understood that those insects which are associated with the vegetation, will definitely move into the new environment created. Not only could they move but also survive and multiply. This is what has exactly happend in this area. The coco plants soon fell prey to a series of insect pests which rapidly destroyed more than 20% of the coco trees. It was observed that first ring bark border appeared. This was followed by leaf eating caterpillars, aphids, and mealybugs. Later tent caterpillars and the larvae of moths threatened the coco fields. Now this is one side of the picture. Let us see the effort made by man for controlling these insects. Massive spraying with DDT, BHC etc. was carried out. As a result of this, bag worms encased themselves in a tough silk sack covered with twigs and pieces of leaf. When man tried to remove this, these insects retreat completely inside the cover. Similarly other pests which also feed on the coco plant bore

into its bark and branches and remained covered. The natural enemies of these pests are predatory and parasitic. Thus the insects which control them were exposed. But unfortunately, the pests are localised and the insects cover larger territories, thereby optimizing the possibility of their contact with insecticides. The net result is that all the enemies of coco pests were destroyed.

Another example can be cited for the environmental imbalance due to human action. The early settlers brought rabbits into Australia for sport and food. These rabbit quickly began to multiply with disastrous results. Entire region was stripped of grass, and valuable water sources were consumed and contaminated. This had a terrific impact on cattle and sheep industries. In order to wipe out these rabbits, rabbit proof fences were built across the country-side for thousands of miles. But all went in vain. Myxoma Virus was introduced as a biological warfare. However, the surviving rabbits developed an immunity to the disease and their populations once more increased.

So far we have discussed only the negative impact of man on biotic environment. There are several positive impacts on the environment due to man's application of knowledge in the field of science and technology. First let us take the introduction of new crops in a new environment. Coffee plant was brought from Arabia and was introduced in the Western Ghats. Today we have good production of coffee in South India. Similarly man introduced hybrid varities of seeds in the agricultural practices. Drought resistant varieties are developed in order to improve the agriculture in the drought prone areas. Thus man with the aid of his skill gained through the development of science and technology has brought several positive impacts on the environment. However, the introduction of new crops, hybrid varieties and new breeds in the animal population have its own impact on environment. But it is not sufficient just to measure the impact individually, because several new problems might crop up simultaneously due to the impact. These has to be studied with a perspective of the environment as a whole. Thus there is a need to study these

environmental problems at greater detail in order to understand the impact of man's action on environment.

EXERCISE—2

Short Answer Questions :

1. Define natural succession.
2. Explain the terms primary and secondary consumers with suitable examples.
3. Define autotroph, heterotroph and tropic level.
4. What are the various elements of abiotic environment ?
5. With suitable example explain the term energy oriented system.
6. Name the major ecosystems of the world.
7. Does the ecosystem differ widely ? Give examples.
8. What do you mean by positive feed back system ?
9. How is the concept of pyramid applied to the spatial variation of organisms ?

Essay Questions :

1. Explain the concept of systems and subsystems in understanding the dynamic aspect of environment.
2. With suitable examples explain how different elements of the physical environment interact with each other.
3. What is the role played by food chain in the biotic environment ?
4. Bring out the interaction between man and biotic environment. Give examples.

3. THE UNIVERSE

We know that the earth is not alone in space. During day time the sun moves across the sky from east to west, during the night there are myriads of stars and the moon. The earth is indeed a part of the Universe around us. The environment on the earth is related to its relation with the sun which is indeed a part of the larger universe.

The relative positions of the heavenly bodies such as the sun, the moon and the stars vary from day to day. The rising and setting of the sun, and the phases of the moon have provided the basis for measuring days, months and years. The annual path of the sun across the sky gave the farmers an indication of the seasons for planting and harvest. The stars provided the direction for travellers on land and sea. Thus a lot of information was collected about the movements of heavenly bodies and used by early man even in ancient periods.

Exploring the Universe

It was earlier believed that the earth was the centre of the Universe and all other heavenly bodies moved around it from east to west. This **Geocentric** concept was prevalent till the middle of the 15th century. This concept was elaborated by Ptolemy in his famous book **Almagest,** published about 140 A D. It was Copernicus (1473—1543), a polish astronomer, who propounded the '**heliocentric**' theory according to which the sun was in the centre and the earth and other bodies revolved round it. It is now known that the sun is not at the centre of the Universe.

Though man has been gazing into the sky for several centuries trying to unravel the mysteries of the Universe, it was not possible to see distant and faint objects with naked eye.

It was Galileo who first used a simple telescope (1609 A.D.) which magnified distant objects. Better instruments were devised for measuring angles accurately. Kepler's laws of motion and Newton's law of gravitation gave further insight into the movements of heavenly bodies.

The mysteries of the Universe have been unravelled in recent decades by the use of more sophisticated instruments and space exploration by artificial satellites. Telescopes with great magnification power have extended the range of observation. Spectroscopes provide a method of analysing light from distant stars. Such spectral analysis has yielded information about the composition, temperature and movement of stars and other bodies. The use of camera along with telescopes has enabled the collection of pictures as permanent records of observations made at different periods. Long exposure of films records much greater information. For example, while a 10 second exposure may reveal 20 stars only, an exposure of 10 hours might reveal 2000 or more stars. Mount Palomar Observatory in California which was set up in 1948 with a large 200 inch telescope coupled with photographic and spectrographic equipment, has added much information during the last 30 years.

An accidental discovery in 1932 that stars emitted radio waves has opened up a new field of astronomical observation. Radio telescopes have been set up to record radio waves emitted by stars. Radio astronomers ' listen ' to the heavenly bodies in the Universe, and identify them according to the intensity of radio waves emitted by them. Objects beyond the range of optical telescopes have been identified by radio telescopes. World's largest steerable radio telescope is at Jodrell Bank in England.

The exploration of space by artificial satellites has made possible observations without the interference of the atmospheres. Satellites have provided much valuable information about planets near the earth such as Mars. Satellites have been launched to gather information about other planets of the solar system. Man's landing on the moon gave a new view of the earth and other heavenly bodies. Space exploration at present is limited to the proximity of the earth.

The Universe around us is so vast that the kilometre cannot be used as the unit of measuring distances. The unit used for measuring vast distances in the Universe is called the **light year.** A light year is the distance travelled by a ray of light during the course of one year travelling at a speed of 300,000 km per second. At this speed the distance travelled in one year would be 9.5 X 10^{12} Km (9,500,000,000,000 Km). Alpha Centauri, the star nearest to the other, other than the sun, is 4.3 light years away. This means the light from the star takes 4.3 years to reach the earth. Our knowledge of astronomical distances involves both time and space dimensions. If an object is observed to be I million light years away from the earth, it gives us not only an idea of distance of the star but also how it was 1 million years ago. The distance of the star at the present time cannot be ascertained from this observation. Thus observations made of distant stars and other heavenly bodies help us to visualise the past and not the present.

The Universe

The Universe, as viewed from the earth, appears to be quite vast, both in space and time dimensions. The radius of the Universe is estimated by some to be about 13, 000 million light years. It is quite likely that there are parts of the Universe which are not visible from the earth. The Universe is considered to be expanding and this means its radius is increasing further. The expansion is taking place uniformly everywhere and it is thought that the Universe is spreading out more thinly. The Universe is boundless and there are no outer limits to its expansion.

The origin of the Universe is explained by three different theories. The **"big bang"** theory considers that the Universe began with a gigantic explosion which led to its expansion outwards. Therefore all bodies in the Universe are racing outwards at very high speeds. The farthest objects observed are moving at nine-tenth of the speed of light. The **"Pulsating"** theory States that there has been alternating expansion and contraction in the universe. According to this theory, the present expansion would slow down, stop and finally begin to contract under the mutual gravitational pull

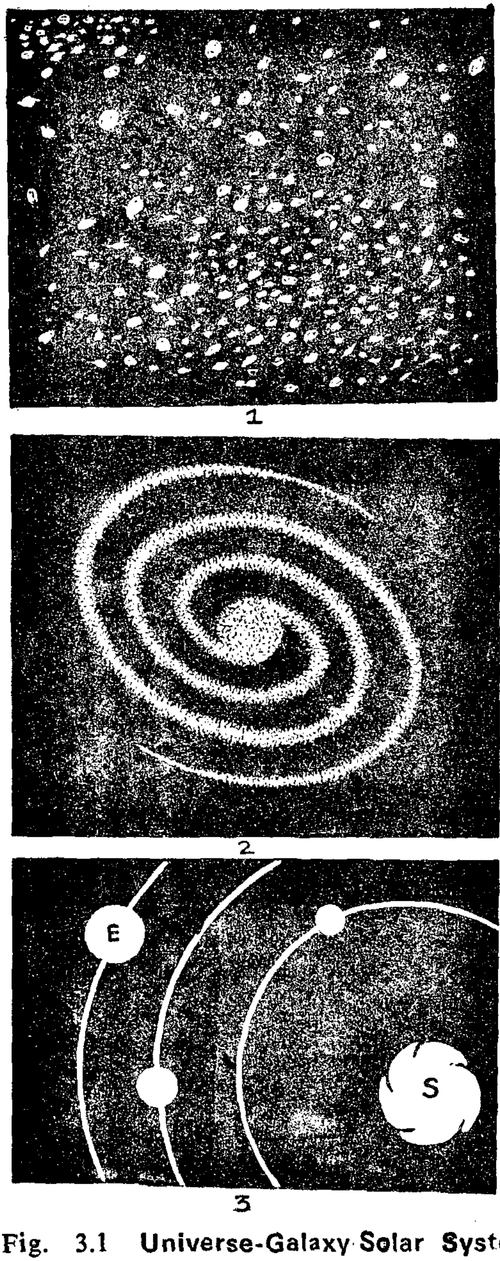


Fig. 3.1 **Universe-Galaxy Solar System**
1. Universe with Galaxies 2. A Galaxy with stars shown as dots
3. Solar System : S-The Sun; E-The Earth

of its parts. When it gets condensed very much it would explode again leading to a phase of expansion. The **"steady state"** theory states that Universe has always been expanding at a constant rate. This theory also assumes that new matter is always being created and in spite of expansion, there is always the same amount of matter in a given volume.

Galaxies

The basic unit of the Universe is the Galaxy which consists of a cluster or grouping of stars. More than 1,000 million galaxies have been observed in the part of the Universe seen from the earth. Galaxies vary widely in size and shape and they are rapidly moving away from one another owing to the expansion of the Universe. It is estimated that an average galaxy may have a diameter of about 30,000 light years and the mean distance separating any two neighbouring galaxies may be about 1,000,000 light years. Galaxies are classified into three types according to their shape. These are spiral, elliptical and irregular types. Galaxies do not occur individually, they occur as clusters.

Our galaxy is known as "The Milky way" galaxy as it is seen as a faint band of light across the night sky. The Milky Way galaxy belongs to a cluster of 17 galaxies called the Local Group. The Milky Way galaxy is a spiral galaxy and has a diameter of 100,000 light years. The galaxy has a thin disc like form with spiral arms extending from it. The galaxy is rotating with velocity increasing from the periphery towards the core. The galaxy nearest to our galaxy is the Andromeda Galaxy which is 2 million light years away. Our galaxy is estimated to contain 100,000 million stars.

Stars

Stars are not gaseous bodies shining by their own light. Stars are so remote from the earth that they appear as points of light even in the most powerful telescopes. Stars are distributed uniformly in any galaxy. They are separated by vast distances. Of the 6,000 and odd stars that are visible to the naked eye, only about 170 are within 30 light years from the earth. Stars rotate on their axes and move along with

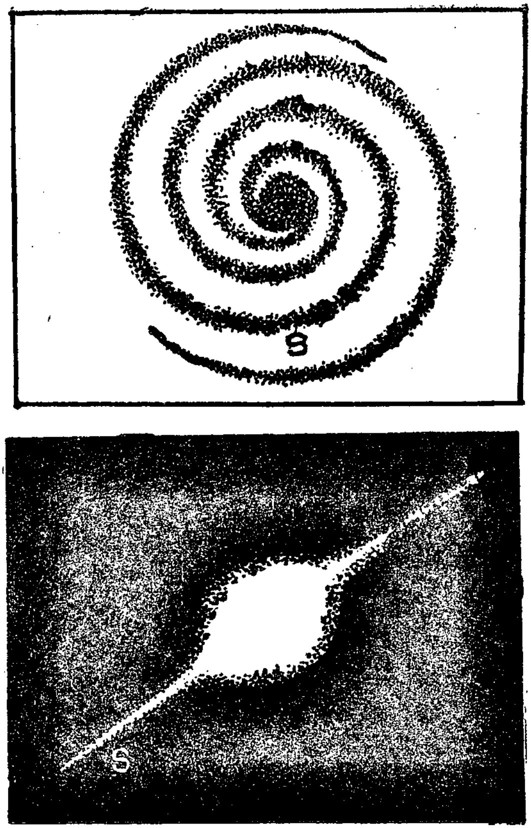


Fig. 3.2

The Milky Way Galaxy

S. Indicates position of the sun

The Upper diagram shows the plan of galaxy with stars as points. The lower diagram shows a cross-sectional view indicating lens shape.

the galaxy in which they are located. Surface temperatures of stars vary from 50,000°C or more (blue stars) to 2,000°C or less (red stars). It is estimated that the stars are predominently made up of hydrogen (75%) and helium (25%). Other elements might add up to 1% to 2% only of the total

mass. The sun is a star of average brightness and magnitude in the Milky Way galaxy.

The Solar System

The Solar system may be considered as a sample of the vast Universe around us. The Solar system consists of the Sun, nine planets, thirtyone satellites, thousands of asteroids or planetoids, millions of comets and swarms of meteors and other tiny particles. The sun is the central body or pivot of the Solar system. All other bodies are held by the gravitational attraction of the Sun and they revolve around the Sun at varying distances from it. Because of its relative proximity, we know much more about the Solar system than about other parts of the Universe.

The Sun

The Sun is a hot gaseous body of large size having a diameter of 1,400,000 Km. that is nearly 109 times the diameter of the earth. The volume of the sun is 1.3 million times that of the earth. As it is predominently made up of light gases such as hydrogen and helium, the density of the sun is only 1.4, that is about 1/4 of that of the earth. The mass of the sun in about 332,00 times that of the earth. The Sun contains 99.9% of the total mass of the solar system. The sun appears larger than other stars because of its relative proximity to the earth.

The Sun is a dynamic body in which nuclear reactions are taking place converting large quantities of matter into energy. It is estimated that every second 657 million tons of hydrogen atoms are converted into 652.5 million tons of helium. The remaining 4.5 million tons of matter is converted into huge quantities of energy. These reactions are responsible for the extremely high temperature in the core of the Sun. The surface of the Sun has an average temperature of 6,000°C. The energy generated in the core of the sun is radiated outwards from the surface of the Sun in the form of electromagnetic waves. The sun shines with a constant power of 380 billion billion watts. The Sun is the primary source of heat and light for the other bodies in the Solar system.

Though the sun is losing its mass at the rate of 4.5 million tons per second, it has enough hydrogen fuel to continue the process for millions of years. The turbulence inside the Sun is reflected at the surface in the form of sunspots, solar flares and prominences. The sunspots appear to be dark spots having a diameter of thousands of kilometers. Their number and distribution changes according to a 11 year cycle. Solar flares and prominences discharge vast quantities of matter from the sun's surface. Such discharges interfere with the transmission of short radio waves. Imagine what would happen if the sun were to radiate more quantities of energy than at present. Any change in the output of energy from the sun would have serious consequences to the earth and other members of the, Solar system.

The Planets

The planets of the Solar system are Mercury, Venus Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto, in the order of increasing distance from the sun. The planets are called so from the Greek word **planetai** which means "wanderers." The ancient Greeks thought that the planets were drifting erratically compared to the relatively fixed stars. Planets rotate about their axes from west to east, that is in an anti-clockwise direction as seen from north. Planets rotate faster than the earth, while others rotate slowly. Planets also revolve around the sun in an anti-clockwise direction in elliptical orbits or paths. Mercury the nearest planet completes one revolution in 88 days, while Pluto the farthest planet takes 248 years to complete one revolution owing to the longer distance to be covered. Planets revolve around the sun more or less in the same orbital plane as that of the earth. Some particulars about the planets are given in Table 3.1.

Planets may be divided into two groups according to their physical and chemical properties. :The inner planets—Mercury, Venus, Earth and Mars — are small in size compared to the outer planets which are farther away from the sun. As the temperature of the planets decreases progressively with distances from the sun, the inner planets are warmer

THE PLANETS

Name of Planets	Mean distance from the sun (Earth's distance from the sun = 1)	Radius of Planet (Radius of Earth = 1)	Density	Time taken for one rotation	Time taken for one revolution around the sun	Number of Satellites	Mean Temperature
Mercury	0·39	0·38	5·5	88 days	88 days	0	+400°C (Day) −1000°C (Night)
Venus	0·72	0·96	5·1	not known	225 days	0	80° to 400°C
Earth	1·00	1·00	5·5	23h56m4s	365·25 days	1	+14°C
Mars	1·52	0·53	3·9	24h37m23s	656 days	2	−15°C
Jupiter	5·20	10·95	1·34	9h55m	12 years	12	−130°C
Saturn	9·54	9·30	0·70	10h29m	29·5 years	9	−180°C
Uranus	19·18	3·90	1·40	10h42m	84 years	5	−170°C
Neptune	30·04	3·50	2·2	15h48m	165 years	2	−200°C
Pluto	39·50	0·47	not known	16h	248 years	0	−230°C

Table 3. 1

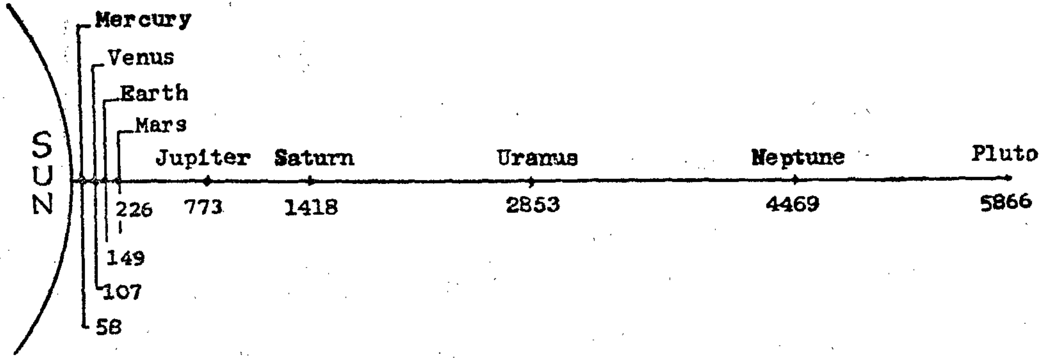


Fig. 3·3

Relative Distances of Planets

Note that the four inner planets are much nearer to the sun than the outer planets.

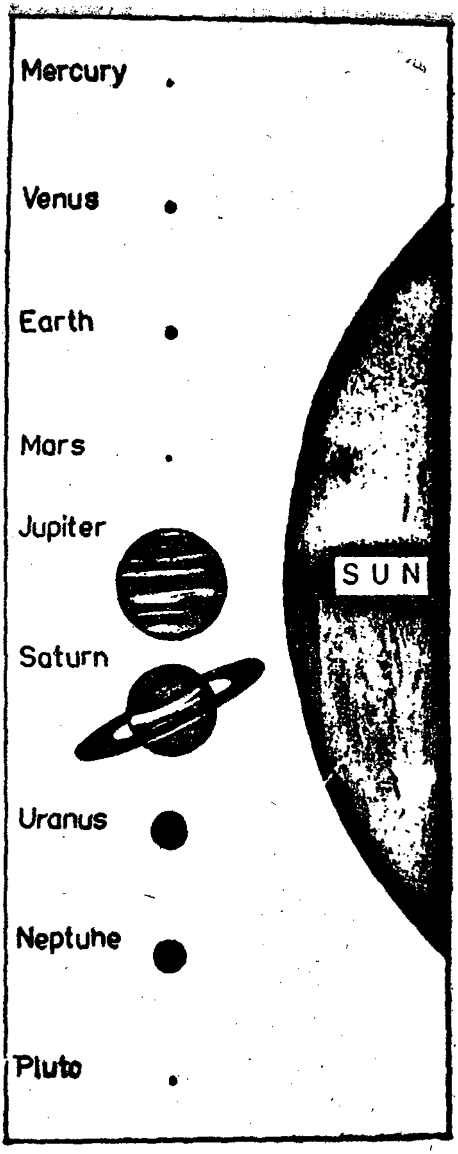


Fig. 3.4
Relative Sizes of Planets
Note the contrast in size between the inner and outer planets. The sun is extremely large compared to the planets.

than the outer planets. The inner planets are considered to have solid metallic core while the outer planets are composed mainly of lighter gases. Therefore the outer planets are less dense than the inner planets. The lighter outer planets rotate faster than the denser inner planets. Jupiter, Saturn, Uranus and Neptune are the four outer Planets Pluto, the farthest planet, is quite small and intensely cold Its physical and chemical properties are not well known owing to its faintness, highly eccentric orbit and vast distance from the earth.

Satellites

Satellites are small heavenly bodies which revolve round the planets, in the same manner as the planets revolving round the Sun. Satellites also rotate about their axes. Inner planets such as Mercury and Venus and the farthest planet, Pluto do not have satellites. The earth has one satellite, the Moon. Mars has two tiny satellites. The outer planets which are larger have a larger number of satellites. Jupiter has twelve satellites; Saturn has nine, Uranus has five and Neptune has two satellites. Besides nine Satellites Saturn has three rings in its equatorial plane. These rings consist of tiny particles which revolve round Saturn upto distances exceeding 10, 000 Km.

Satellites vary very much in size. One of the satellites of Mars is only 8 Km in diameter and a satellite of Saturn is as big as Mercury. Satellites are so tiny that they do not generally have an atmosphere. Some of the satellites of Saturn and Neptune revolve in a direction opposite to the direction of rotation of the planets. Satellites shine in the sky by reflected sunlight in the same manner as the planets. Satellites are held by the gravitational force of the planets. Satellites are composed of the same material of which the respective planets are composed.

The Moon is a satellite of the Earth. It has a diameter of 3480 Km and its mean distance from the earth is 384, 900 Km. The moon rotates rather slowly on its axis, so that one rotation takes 27 days and 8 hours. This means a 'Lunar day'

extends over two weeks followed by 'Lunar night' of two weeks. Thus the moon is exposed to extreme heat during the long period of exposure to the sun and extreme cold during the long night. The moon lacks an atmosphere and there is no trace of water vapour.

The average density of the moon is 3.3 and appear to be made up of material similar to those found on the surface layers of the earth. The surface of the moon is highly irregular consisting of high mountain ranges and large plains called 'seas.' Craters of varying sizes abound on the surface. These craters are believed to have been produced by the impact of meteors.

The revolution of the moon around the earth leads to varying proportions of the lighted half of the moon being seen from the earth. As the period of rotation and revolution are nearly the same, only about one half of the moon, the same face is visible from the earth. The opposite face is hidden from the earth. When the moon is in a straight line between the earth and the sun, the lighted half of the moon is not visible from the earth. This is the position of the new Moon. When the moon is in a straight line with the sun with the earth in the middle, the lighted half is visible fully and this marks Full Moon. Between New Moon and Full Moon, the proportion of the moon visible from the earth gradually increases; between Full Moon and New Moon the proportion of the moon visible from the earth gradually decreases.

Asteroids

Asteroids are minute planetary particles (planetoids) which revolve around the sun between the orbits of Mars and Jupiter. The largest is about 800 Km in diameter and the smallest visible ones are about 2 Km in diameter. Besides 30,000 large asteroids, there are millions of smaller asteroids of the size of boulders and pebbles. Smaller asteroids are of irregular shape. The total mass of all asteroids is only a small fraction of that of the earth. While most of the asteroids revolve in the same orbital plane as the other

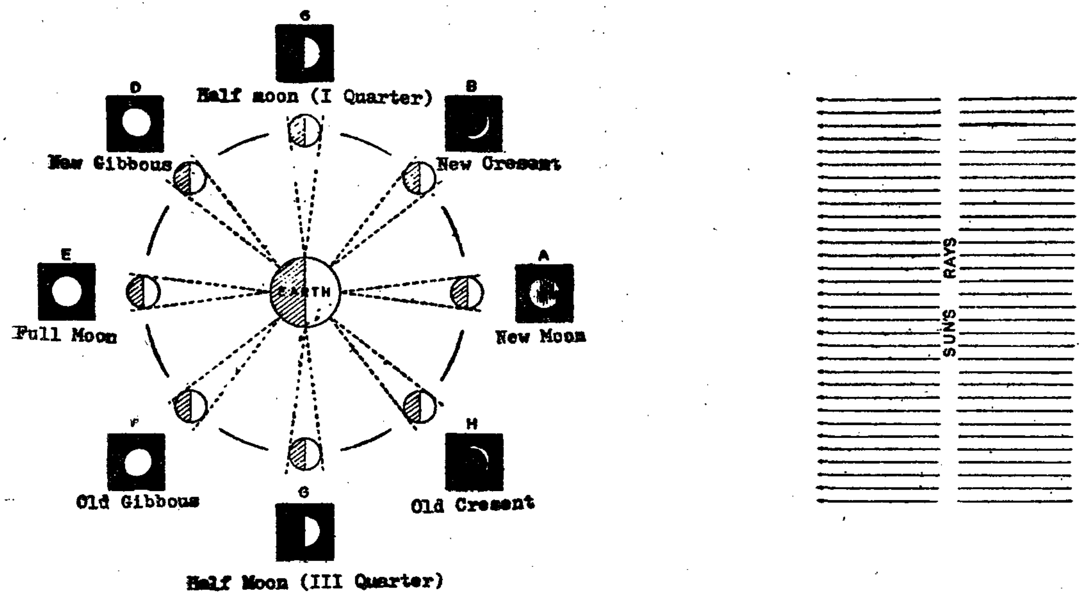


Fig. 3.5

Phases of the Moon

Note that in all positions half the moon is illuminated by the sun. But the portion of lighted half seen from the earth varies.

planets, some have irregular orbits. Some of them come quite close to the earth and may strike the earth. Meteorites which fall on the earth are probably derived from the belt of asteroids.

Meteors

Meteors are commonly called shooting stars though they are very much unlike stars. Meteors appear as sudden streaks of light moving across the night sky. Meteors pass through the atmosphere at speeds of 40 to 50 Km / sec and this causes ionisation of air in their path. We see the cylindrical trail of the ionised gases left by a passing meteor. Millions of meteors enter the earth's atmosphere daily and most of them get completely vapourised before they reach the earth's surface, The atmosphere protects the earth's surface from the impact of meteors.

Meteorites

Larger meteors do not get completely vapourised in their passage through the atmosphere. They fall on the earth's surface as solid particles. These are called meteorites. Meteorites give an indication of the type of material reaching the earth from space. Some meteorites consist mainly of iron (80 to 90%) others resemble basic igneous rocks in composition. It is estimated that millions of meteorites fall on the earth every day and this adds about two million tons of matter to the earth every year.

The impact of large meteorites has produced large craters on the earth's surface. Meteor crater in Arizona State of the United States is the best example. A swarm of meteors hit an uninhabited mountain slope in Siberia in 1948.

Comets

Comets are quite different from meteors in many respects. Unlike meteors, comets are rarely seen in the sky. While meteors appear as sudden streaks of light lasting for a few seconds, comets cover a large part of the sky and may be visible for several weeks or months. Comets are much larger than meteors in size. Comets have well defined heads and elongated

tails. Some comets have heads 100,000 Km across and tails may extend to millions of Kilometres.

Comets consist of solid particles of matter similar to meteorite, covered by thick layer of frozen ammonia, methane and ice. Comets have extremely elongated orbits unlike the planets. As the comet approaches the sun, the frozen gases get vapourised explosively and this diffuses into space and forms a tail. The long tail of a comet usually extends in a direction away from the sun owing to the pressure of radiation from the sun. While some comets appear regularly at fixed intervals of a few years, other comets have not been observed periodically. The most famous periodic comet is Halley's comet which appears regularly at intervals of 75 years. The sighting of this comet has been recorded regularly since 240 B.C. and this will be seen again in 1986.

The Earth

If we want to locate the Earth in the Universe, we have to look for the Milky Way galaxy out of several millions of galaxies in the Universe. Having located the Milky Way galaxy, we have to look for the Sun, one of the several millions of stars in the galaxy. The sun is not however the largest or the brightest star in the galaxy. If we locate the sun, the earth is the third planet located at an average distance of 150 million Km. from the sun.

The Earth is a unique planet in several respects. The most important feature of the earth is that it is habitable by man and other forms of life. The evolution and growth of various forms of life on the earth is made possible by favourable environmental conditions. The distance of the earth with reference to the sun is such that it is neither too hot nor too cold. The range of variation in temperature is not large so that there are no extremes of temperature. The period of rotation of the earth is such that there is not much variation between day and night. If the earth were to rotate much slower than at present, there would be greater extremes of temperature between day and night. The absence of extremes

of temperature is also due to the presence of the atmosphere and oceans.

The earth is fortunate to have a layer of atmosphere rich in oxygen. Oxygen in the atmosphere sustains all forms of life on the earth. The atmosphere acts as a blanket in two-ways. It prevents the inflow of harmful ultra-violet rays to the earth's surface and reduces the outflow of heat from the earth's surface during the night. The circulation of the atmosphere diffuses the heat through the earth-atmosphere system and thus prevents excessive heating or cooling.

Another unique feature of the earth is the abundance of water in the form of oceans. The temperature of the earth is such that water is present in all three states — solid, liquid and gaseous. Besides the oceans, water occurs on the land in the form of rivers, lakes and other water bodies. Water in frozen state such as ice and snow is seen in high mountain ranges and Polar regions. Water occurs in the form of water Vapour — a gas — in the atmosphere. The presence of abundant quantities of water is also responsible for the abundance of life forms on this planet.

Size and Shape of the Earth

The earth like other planets is spherical in shape. The rotation of the earth has caused slight bulging at the equator where the velocity is maximum. Therefore, the Equatorial radius (6378 Km) is slightly greater than the Polar radius (6356 Km). This difference is so small compared to the overall size of the earth that the earth may be considered as a sphere. The shape of the earth is more precisely described as an oblate spheroid. The circumference of the earth is about 40,000 Km. The distance from the Pole to the Equator is 10,000 Km. The earth is the largest planet among the four Inner planets.

IMPORTANT DIMENSIONS OF THE EARTH

Equatorial radius	6378 Km
Polar radius	6356 Km
Mean radius	6367 Km

Equatorial circumference	40,075 Km.
Polar circumference	40,024 Km.
Total surface area	510 million 89 Sq. Km.
Volume	1,082,000 million C. Km.
Mean density	5.5

You are already familiar with the evidences regarding the spherical shape of the earth. The exploration of space by satellites has confirmed beyond any doubt the spherical shape of the earth. The observations of the earth by the astronauts from the moon and the photographs taken from space have indicated the spherical shape.

Motions of the Earth

The earth rotates on its axis and revolves around the sun. The direction of rotation is from west to east. Therefore, the sun, moon and the stars appear to move from east to west, a direction opposite to that of the rotation of the earth. The time taken for one rotation is about 23 hours and 56 minutes The rotation of the earth causes alternating day and night, as only one half of the earth is exposed to the sun at any one time. The rotation of the earth brings about differences in time between different places on the earth.

The earth revolves around the sun in an elliptical orbit The distance of the earth from the sun varies from a minimum of 146 million Km. **(Perihelion)** to a maximum of 151 million Km. **(Aphelion)**. An imaginary plane passing through the sun and all points in the earth's orbit is known as the **Plane of the ecliptic.** The earth's axis is inclined at an angle of $66\frac{1}{2}^\circ$ from the plane of the ecliptic or $23\frac{1}{2}^\circ$ from the vertical plane. The time taken for one complete revolution around the Sun is about $365\frac{1}{4}$ days.

Structure of the Earth

A knowledge of the structure of the earth is necessary in order to understand phenomena like volcanic eruption, earth movements and earthquakes. As the deepest bore holes do not exceed a few kilometres of depth, we have no direct evidence regarding the structure of the interior of the earth.

It is known that temperature increases at an average rate of 1° C for 32 metres of depth below the surface. At this rate even at a depth of a few kilometres from the surface, the temperature would exceed of the melting point of most of the substances found on the earth's surface. Along with increase in temperature there is considerable increase in pressure also with depth. Such combination of high temperature and high pressure cannot be realised in the laboratory. We know that the matter in the interior layers behaves like a solid under certain conditions.

Whenever there is a deep crack or fissure in the surface layer of the earth, pressure is released and material becomes molten and flows to the surface through the crack or fissure. This type of movement is responsible for volcanic eruptions. The processes which take place in the interior layers of the earth cause earth movements and earthquakes. Besides changes in physical conditions such as temperature, pressure and density, there are also changes in chemical composition in the interior layers of the earth.

A lot of information has been obtained about the interior layers of the earth from a study of the passage of the earthquake waves through the earth. It is now known that the earth consists of concentric shells or layers one below the other. These layers progressively increase in density from the surface towards the centre of the earth.

The outer layer of the earth is known as the **crust** of the earth. The average thickness of the crust is 60 Km. The crust is thicker below the continents than below the ocean floors. The crust is ususally divided into two layers on the basis of chemical composition. The top layer which is lighter is known as the **sial** layer. The sial layer is made up of silicates of aluminium and other light metals. Continents are mainly made up of the sial layer. Below this layer is the denser **sima** layer. This layer consists mainly of silicates of magnesium and other denser metals. The sima layer is exposed on the ocean floors. The average density of the earth's crust as a whole is less than 3.0.

Below the crust of the earth is a thick layer known as the **mantle**.. This layer extends upto a depth of about 2900 Km. from the surface. The mantle consists of a mixture of silicates and metals. The metallic content increases with depth. The density of the mantle varies from 4.5 to 5.5, with density increasing with depth.

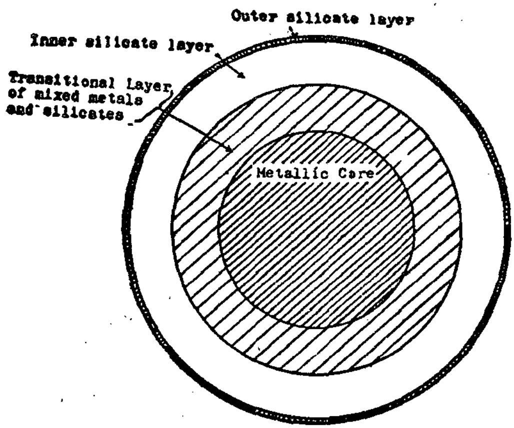


Fig. 3.6

Structure of the Earth

1. **Crust**—Outer silicate layer.
2. **Mantle**—Inner silicate layer and Transitional layer of mixed metals and silicates.
3. Core

The **core** of the earth lies beneath the mantle, at depth exceeding 2900 Km. The core is considered to be metallic in composition comprising of iron and nickel. The average density of the core of the earth is 11.0. The metallic core of the earth probably accounts for earth's magnetism.

EXERCISE—3

Short Answer Questions:

1. What are heavenly bodies?
2. Distinguish between 'Geocentric' and 'Heliocentric' concepts.
3. What is a 'light year'?
4. What are galaxies?
5. Describe the Milky Way Galaxy.
6. What processes take place inside the Sun?
7. Distinguish between Inner and Outer planets.
8. Name the planets in the order of increasing distance from the sun.
9. Write a short note on "satellites".
10. What are asteroids? Where are they found?
11. Distinguish between meteors and comets.
12. What are meteorites?
13. How would you locate the earth in the Universe?
14. Distinguish between the crust and the mantle.

Essay Questions:

1. Describe the different methods adopted for exploring the Universe.
2. Give an account of the moon as a satellite of the earth.
3. In what respects is the earth a unique planet?
4. Describe the structure of the earth.

4. The Changing Face of the Land—I.

The surface of the land is not uniform except over small areas of a few square kilometres. The elevation of the land above sea level and the slope of the land both vary from place to place. Lofty mountain ranges such as the Himalayas have peaks exceeding 8,000 metres above sea level, some parts of land such as the Jordan river valley in Israel are a few kilometres below sea level. The slope of the land varies from flat alluvial plains to steep slopes of mountain ranges and cliffs along the coast. The variation in the elevation and slope of the land are reflected in the variety of landforms such as mountains, plateaus, plains, ridges, valleys, and others.

It is often assumed that landforms are relatively permanent and they do not change. But change is as much typical of land forms as the atmosphere or the hydrosphere. Changes in landforms may be produced sometimes suddenly by volcanic eruption, earthquakes, floods, etc. Such sudden changes are obvious to us. Another type of change that is not so striking is the slow erosion of the land by rivers and other agents. Changes in landforms are brought about in course of time by the action of various processes on the materials of the earth's crust. Let us first examine the salient features of the materials of the earth's crust.

Materials of the Earth's Crust

Composition of the Earth as a Whole and the Crust

Element	Earth as a whole % by weight	Crust % by weight
Iron	34·6	5·0
Oxygen	29·5	46·6

Silicon	15.2	27.7
Magnesium	12.7	2.1
Aluminium	1.1	8.1
Calcium	1.1	3.6

We have seen in the last chapter that the crust of the earth is lighter in density than the mantle and the core. This is because lighter elements are more abundant than denser metals. Oxygen (46.6% by weight) and Silicon (27.7%) are the most abundant elements in the earth's crust. The other elements in order of abundance are Aluminium (8. 1%), Iron (5. 0%), Calcium (3. 6%), Sodium (2. 8%) Potassium (2.6%) and Magnesium (2. 1%). It will be seen from the above that the most abundant element in the earth as a whole, namely iron, is found only in relatively small amounts in the crust. The chemical composition of the crust is of great significance from the point of the environment of life on the earth. The crust is the source of the soil layer and other sediments and also of the salts of the sea. The relative richness of the crust in calcium, sodium, potassium and magnesium is of great significance for plant growth. The crust is the direct source of most of the elements of environmental significance.

Rocks

The crust of the earth is made up of rocks of various types. The term 'rock' includes hard and resistant materials like granite and also other materials like sand, clay and loose materials. Rocks are aggregates of minerals of various types. Rocks vary widely in their physical and chemical properties and their ages of formation.

A mineral is a naturally occurring inorganic material having a definite chemical composition and physical properties by which it may be easily identified. As oxygen and silicon are the most abundant elements in the earth's crust, Quarts (silicon dioxide) is the most common rock forming mineral. Silicate minerals, such as feldspar and mica, are made up of silicon, oxygen, and one or more of the metallic elements. Silicate minerals are more common in the rocks. Carbonate minerals such as calcite and dolomite, sulphate minerals such as

gypsum and chloride, minerals such as rock salt are other types of minerals. More than 2, 000 types of minerals are known to be present in the crust. These combine in different proportions to form various types of rocks. Therefore rocks do not have definite chemical composition like minerals.

Rocks are classified into three major types according to their mode of origin. **Igneous** rocks are those which are formed by solidification of molten magma due to cooling. **Sedimentary rocks** are made up of sediments usually laid down below sea level in the form of layers. **Metamorphic rocks** are formed by the alteration of other rocks by extreme heat or pressure or both.

Igneous Rocks

Igneous rocks are made up of crystals of minerals formed during the cooling of molten magma. When the molten magma reaches the earth's surface, it gets solidified rapidly and the rock develops crystals of small size. Such rocks are called **Volcanic** or **extrusive** rocks. Such cooling of magma takes place in volcanic regions where the magma reaches the surface from great depths. Basalt is an example of volanic rock.

Cooling and solidification of magma may also take place at some depth below the surface. In such places, the magma cools down slowly and therefore crystals of large size are formed. These rocks are called **intrusive** or **plutonic** rocks. Granite is an example of plutonic rock.

Igneous rocks may also be classified into **acidic** or **basic** rocks on the basis of chemical composition of the magma from which they are derived. Acidic rocks are less dense, lighter in colour and contain greater quantities of quarts and feldspar. Basic igneous rocks are denser, have a darker colour and contain a higher percentage of heavier minerals like mica, hornblende, pyroxene and olivine.

Sedimentary Rocks

The formation of sedimentary rocks is a slow process as the accumulation of sediments on the floors of seas, lakes or rivers

takes place gradually. These loose particles get hardened into rocks by the presence of cementing materials such as lime between the particles of sediment or by the pressure of overlying sediments. As the sediments are deposited in water bodies, they get sorted out according to size of particles. Sedimentary rocks have distinct layers or strata consisting of particles of different sizes or colours. These rocks are therefore called **layered** or **stratified rocks.**

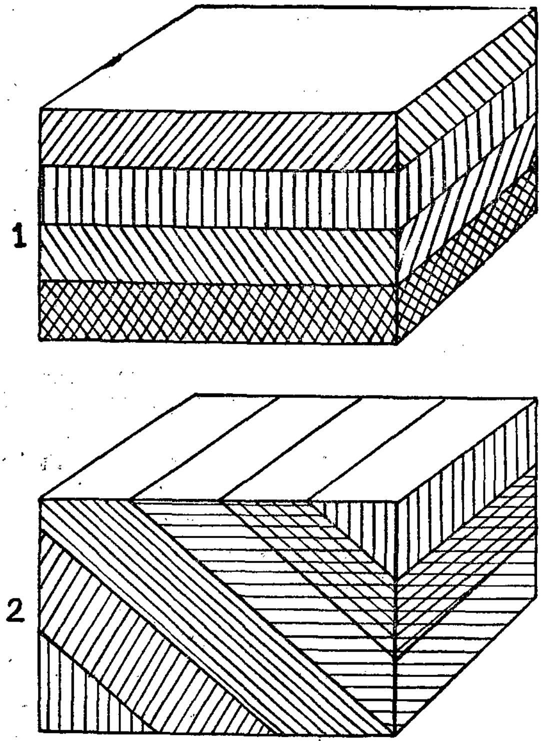


Fig. 4.1

Sedimentary Rocks

1. Horizontal bens 2. Tilten bens

Sedimentary rocks are classified according to the types of sediments from which they are derived. Sediments derived from the erosion of the land by rivers, glaciers, winds or waves are

known as **clastic sediments.** Gravel, sand and clay are examples of such sediments. Sediments of gravel get converted to a rock called conglomerate; deposits of sand become sandstone. Deposits of clay form a rock called shale. Sedimentary rocks may also be formed from organic sediments such as remains of plants and animals. Shells of marine organisms and corals may form a rock called limestone. Coal and lignite are examples of beds of sedimentary rocks derived from plant remains. Rock salt is an example of sedimentary rock derived from chemical sediments caused by evaporation of saline water.

The type of sedimentary rock at a place gives an indication of the environmental conditions under which the sediments were deposited. The age of the rock may be estimated from the plant and animal remains which are embedded between layers of sediments. These plants and animal remains are known as **fossils.** The geological history of the earth has been deciphered from a study of fossils.

Though the sedimentary rocks are the most widespread on the surface of the land, they are rarely found in the same manner in which they were first laid down. Sedimentary rocks are usually laid down as horizontal layers one above the other. But most of the sedimentary rocks on the surface of the land masses have been disturbed from their horizontal position. They have been tilted, folded and displaced owing to movements of the earth's crustal layers.

Metamorphic Rocks

Metamorphic rocks are also known as **altered rocks,** as they are derived from the alteration of pre-existing rocks. The process of alteration may be extreme heat. For example, when magma erupts through a narrow crack or fissure, rocks adjoining the crack or fissure are heated up by contact with molten magma. Extreme heat leads to the melting of some of the mineral and the formation of new minerals due to chemical changes. Thus a new rock type is formed by alteration of pre-existing rock. Similarly, when rocks are subjected to extreme pressure during folding or other earth movements, metamorphic rock gets formed.

Metamorphic rocks may be derived from either igneous or sedimentary rocks. It is difficult to identify the original rock from which a metamorphic rock has been formed. Metamorphic rocks exhibit usually a banding of minerals of various types. Minerals get arranged in parallel bands and this somewhat resembles the strata of sedimentary rocks. Metamorphic rocks are crystalline while sedimentary rocks are not so.

Granite gets metamorphosed to a rock called gneiss. Shale is altered to slate; limestone becomes marble and sandstone is altered to quartzite. Metamorphic rocks are usually more resistant than the rocks from which they are derived.

Besides forming the base for the formation of soils, the rocks of the earth's crust provide all the minerals needed by man. While metallic minerals are more commonly found in igneous and metamorphic rocks, mineral fuels such as coal, lignite and petroleum are obtained from sedimentary rocks. Rocks of the crust form the medium in which a variety of landscapes are carved by the action of various processes.

Processes of Landscape Development

Various types of processes act on the crust continuously carving out a variety of landscapes. These processes may be divided into two broad groups-the **internal processes** and the **external processes.** The Internal processes operate in the interior layers of the earth. This leads to disturbances in the earth's crust by volcanic action, earth movements and earthquakes. The operation of internal processes are aided by the release of heat and energy by radio active minerals in the interior layers. It is not possible to observe the working of the internal processes. Internal processes affect both the land masses and the ocean floors.

The external processes act on the surface of the land masses. These are the result of the interaction between the atmosphere and hydrosphere with the surface of the land. The rocks of the crust get broken down and transported by rivers, winds and waves. The force of gravity aids the external processes and helps in moving the materials down the slope. Thus the action of the external processes helps to reduce the inequalities on the surface

of the land. These processes are known as **gradational processes** These processes affect the land masses only and their action may be observed and measured.

The nature of landform in an area depends on the relative importance of the internal and external processes and the period during which these processes have been operating in the area. For example, the Himalaya mountains owe their high elevation to their recent uplift by the internal processes. The external processes have not had enough time to wear them down. On the other hand the Aravalli mountains, which were formed in much older period than the Himalayas, have been very much reduced owing to the continued action of the external processes. Time is therefore an important factor in landscape development. Even though the same processes may be operating in an area, the form of the landscape gets modified with time.

Internal Processes

The action of the internal processes is reflected in the relative instability of the earth's crust. The Himalaya mountains having peaks exceeding 8,000 metres of elevation above sea level consist of sedimentary rocks with marine fossils embedded in them. This means these rocks which form the Himalaya mountains must have been deposited in shallow seas millions of years ago and later uplifted due to internal forces. During the uplift, the layers of sedimentary rocks have been tilted, folded and displaced over great distances. The presence of submerged forests off the Bombay coast indicates downward displacement of the crust. The sudden eruption of volcanoes and the displacement of the crust leading to earthquakes are other visible effects of internal forces.

Earth Movements

Movements of the earth's crust are known as **tectonic movements.** Such movements may take place suddenly or slowly along lines of weakness in the earth's crust. Tectonic movements may be classified into two types **epeirogenic movements** and **orogenic movements.** Epeirogenic movements involve mainly displacement of the crustal layers in a vertical plane. Such vertical movements of uplift and subsidence have been

mainly responsible for the formation of continents and oceans. These movements are therefore known as continent building movements.

Vertical displacement of the crust usually takes place along lines of weakness such as cracks or fracture. The vertical movement of the rocks along the line of fracture is known as **faulting**. A steep slope or scarp is produced along the strata.

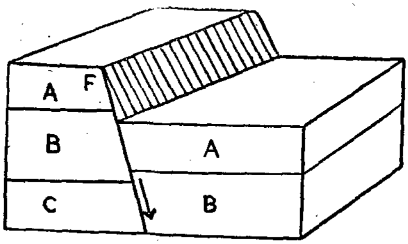


Fig. 4.2

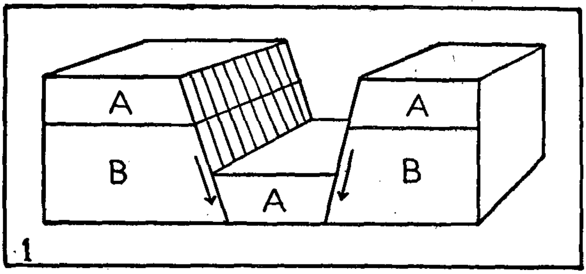
Fault Scarp

F – fault line – Note that bed A has slipped down on the eastern side of the fault.

Such **fault scarps** may extend for several kilometres in an almost straight line. When two faults adjoin one another, the land between the faults may be displaced downwards or upwards. When the portion of the crust between two faults gets displaced downwards, it is known as a **rift valley**. The Great Rift Valley of East Africa is the best example. Parts of the valleys of Narmada and Tapti rivers in India are also considered as rift valleys.

When the portion of the crust between two faults gets uplifted, it forms a plateau known as a **horst** or **block mountain**. The Vosges and Black Forest on either side of the Rhine Rift Valley are considered as typical examples. The Nilgiri hills may be considered as an Indian example.

Vertical displacements along fault lines has produced steep slopes along the coasts of Africa. Greater part of the continent of Africa consists of plateaus uplifted by tectonic movements along the coast. The steep slope of the Western Ghats along the West Coast of India is considered to be due to faulting.



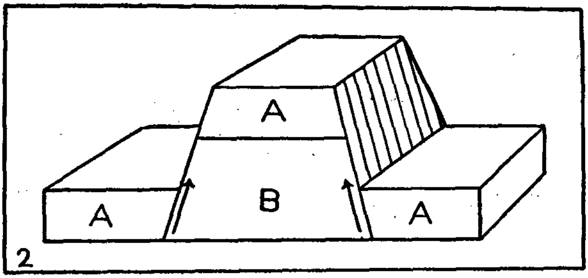
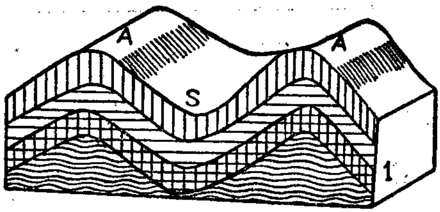


Fig. 4.3
Movements along Fault
1. Rift Valley 2. Horst or Block Mountain

Orogenic Movements

These movements primarily involve horizontal movements of the earth's crust. The forces causing horizontal movements may be compressional or tensional in nature. Compressional forces act from two opposite directions leading to a bending or folding of strata. Tensional forces work outwards pulling the crust in two opposite directions leading to breaking or fracturing of the strata in the crust.

When horizontal compressional forces affect a region of sedimentary rocks, the rocks are folded by compression. A simple fold comprises alternating upfold or **anticline** and downfold or **syncline.** When the slope of the beds is the same on both sides of the fold, it is known as a symmetrical fold. A symmetrical fold has steep slope on one side and gentle slope on the other side of the fold. Simple folds with alternating anticlines and synclines are not commonly found. Usually folded regions



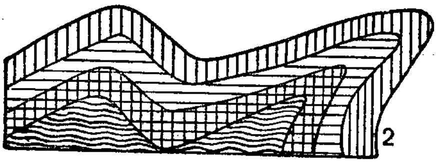


Fig. 4.4

1. Symmetrical folds A—Anticline S—Syncline
2. Tilted folds

have a complex structure with folds tilted at various angles and faults displacing the strata.

The formation of folded mountains is a slow process which takes millions of years. Three stages are usually distinguished in this process. The first stage involves the accumulation of large quantities of sediments in a shallow sea. The sediments are derived from the erosion of adjoining land masses. The floor of the sea subsides gradually and thus permits accumulation of sediments over a long period of time. The second stage represents the action of compressional forces leading to folding of the layers of sediments. The third stage represents uplift of the folded strata. This takes place slowly. The Himalaya mountains are still considered to be rising.

The formation of fold mountains has taken place during many periods in the long geological history of the earth. The most recent mountain building took place about 30 million years ago. These youngest fold mountains are among the highest mountain ranges in the world. The older mountain ranges have been eroded and worn down by external processes.

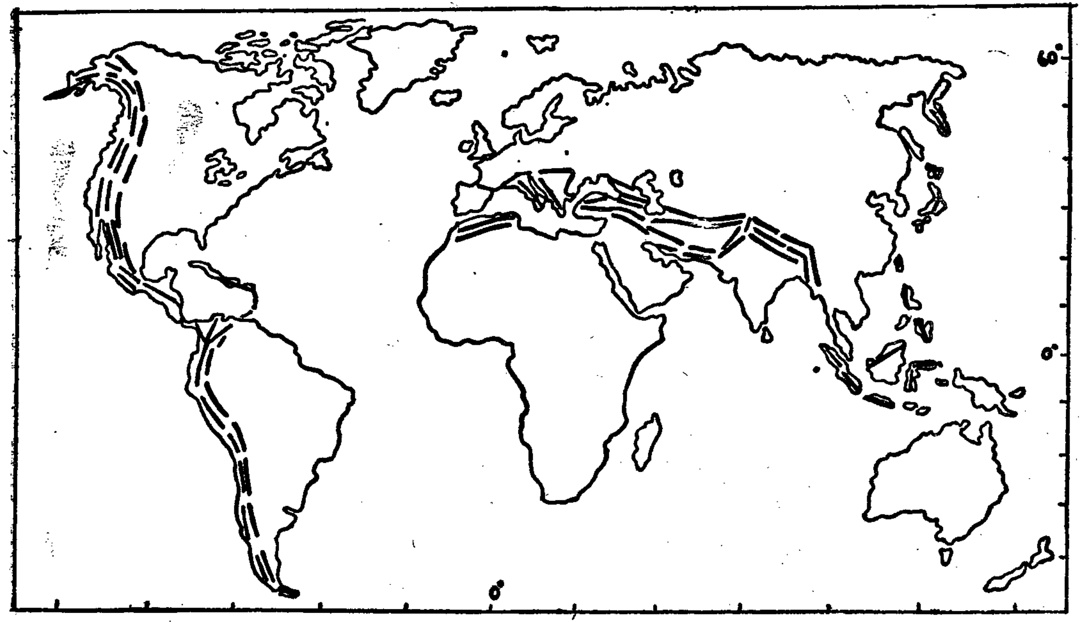


Fig. 4.5

Fold Mountains

[The map shows recently folded mountain ranges. Note the Mid World Mountain belt and the Circum-pacific Mountain Belts

The recently formed fold mountain ranges are found in two major belts. The Circum-pacific mountain belt includes, the Andes (S. America), the Rockies (N. America) and the island arcs off the coast of Asia stretching from the Aleutian islands to Indonesian islands. The Mid-world mountain belt comprises the mountain ranges such as the Alps, the Himalayas and others which extend in a general east-west direction across Europe and Asia.

Volcanoes

Volcanoes are produced by the eruption of molten magma from the interior of the earth. Usually eruption takes place at a point called the **vent.** As material accumulates around the vent, a conical hill with concave slope is formed. The summit of the volcanic cone is marked by a small depression called the **crater.** Fuji Yama in Japan and Vesuvius in Italy are examples of volcanoes of the cone and crater type.

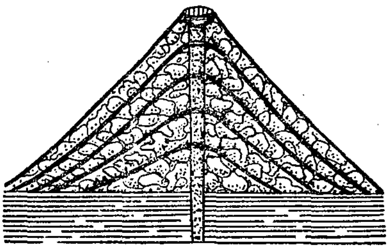


Fig.4.6

Volcanoe

P—Volcanic Pipe C—Crater

[Note alternating lava sheets shown in black and deposits of ash.]

In some places molten magma may erupt along a long fissure in the crust. Such fissure eruptions usually give rise to extensive lava plateaus. The Deccan trap region of Peninsular India is a typical example of a vast lava plateau extending over 500,000 Sq.Km. Fissure eruptions have taken place more recently in Iceland.

Volcanoes are usually classified into three types on the basis of their frequency of eruption. **Active volcanoes** are those which erupt fairly frequently. **Dormant volcanoes** are those which have erupted in historical periods but have remained quiet since then. **Extinct volcanoes** are those which have not erupted in historic periods. Extinct volcanoes may erupt suddenly. For example, Krakatoa volcano in Indonesia which was considered an extinct volcano erupted suddenly in 1883.

The material erupted from a volcano includes matter in solid, liquid and gaseous states. Solid matter comprises particles of rocks blown up during an explosive eruption, smaller particles called volcanic cinder, volcanic ash and dust particles. The gases erupted include steam, hydrogen, sulphur dioxide, carbon dioxide, etc. These gases which remain dissolved in the magma, escape with great violence due to release of pressure.

Liquid matter erupted from a volcano flows as tongues of lava down the slope of the volcano. Lavas which are basic in composition, flow freely over long distances. Such volcanoes have gentle slopes. The volcanoes of Hawaiian islands erupt basic lava. Acid lavas do not flow readily and they get solidified around the vent to form a conical hill with steep slopes. When the volcanic vent is blocked by solidified magma, eruption takes place explosively.

Most of the volcanoes of the world are known to occur in the belts of recently folded mountain ranges. The Circum-pacific belt is known as the 'ring of fire' and this includes the volcanoes of the Andes and Rockies, Japan, Indonesia and New Zealand. The Mid-world mountain belt has fewer volcanoes. Volcanoes are associated with Great Rift Valley of East Africa, the mid-oceanic ridges and other lines of weakness in the ocean floors.

Volcanoes cause extensive damage to life and property during explosive eruption. For example, Mt. Pelee on the island of Martinique erupted suddenly in 1902. A glowing avalanche of lava and hot clouds swept down the slope dest-

royying the town of St. Pierre killing all of its inhabitants. When volcanic eruptions take place along the coast, this may give rise to high tidal waves which cause destruction of life and property in the coastal tracts. Volcanoes also have beneficial effects. The soils derived from volcanic deposits are fertile and this is responsible for the high population density in the tiny island of Java in Indonesia. The lava plateau region of the Deccan trap in India has fertile black regur soils.

Earthquakes

Earthquakes are tremors or sudden movements of the earth's surface caused by disturbances in the earth's crustal layers. This is similar to what happens when a stone is thrown into a pond. This generates a series of concentric waves which spread out in all directions concentrically from the point at which the stone strikes the water surface. Similarly, the disturbance in the earth's crust leads to the propagation of waves in all directions from the centre of disturbance. These waves are called **seismic waves.** The centre of disturbance from which the waves originate is called **seismic focus.** A point vertically above the focus on the surface of the earth **is** called the **epicentre** of the earthquake.

The focus of earthquakes uaually lie within a depth of 60 Km., from the surface. A few earthquakes have foci at depths of hundreds of kilometres. When earthquake takes place, a lot of energy is released and this causes rapid movements of the earth's crust. The passage of earthquake waves is recorded in instruments called **seismographs.** The tremors of the earth are recorded in the form of waves on a sheet of paper attached to a cylindrical drum rotated by clockwork; the intensity of the wave and the time of its passage are recorded on the graph.

Earthquakes occur frequently in unstable portions of the earth's crust. Though hundreds of earthquakes are recorded daily, strong earthquakes which cause large scale destruction are less frequent. A large number of strong earthquakes are

produced by sudden movement along fault lines. The San Andreas fault in California is an example of a fault line along which earthquakes have occurred in the recent decades. Earthquakes are also associated with volcanic eruptions. Earthquakes occur frequently in the recently folded mountain belts, where the crust is unstable.

The passage of earthquake waves through the crust leads to a displacement of the surface vertically or horizontally or both. As the waves travel rapidly, buildings are destroyed, roads and railway lines get disrupted; fissures may open on the surface, and land slides may occur on mountian slopes. Rivers may change their courses and dams may breach causing floods. When the epicentre of an earthquake is located on the sea floor, huge seismic sea waves called **tsunamis** are produced. These waves may traved over long distances at an average rate of 500 km per hour and cause widespread destruction along the coasts. The area near the epicentre suffers maximum damage and the extent of damage decreases progressively with distance from the epicentre.

Earthquakes occur frequently in the foothill zone of the Himalayas. This is a zone of instability in the earth's crust. Earthquakes of great intensity have occurred in the Kashmir Valley (1823 and 1885), Kumaon Hills (1303), North Bihar (1934), Cachar (1869) and Assam (1897 and 1950). The Kutch earthquake (1819) took place in a region of slow subsidence. Recently a severe earthquake occurred in Kinnaur district of Himachal Pradesh on 19th January 1975. This caused extensive damage to life and property. As the roads were disrupted, food and relief material had to be rushed by helicopters. The Deccan plateau is relatively free from earthquakes. But in 1967 the Koynanagar township near the Koyna Dam was rocked by an earthquake.

Man's activity is also responsible for producing earthquakes. Pumping of oil from oil fields, injection of large quantities of water into oilwells and impounding of large quantities of water in reservoirs behind huge dams disturb the equilibrium in the crustal layers. Earthquakes have occurred in such

places in order to release the stresses and strains produced by human activity. Earthquakes have been recorded in the vicinity of Hoover Dam in the United States and Kariba dam in Zambia.

The distribution of epicentres of earthquakes shows a close relationship with the belts of folded mountain ranges and volcanoes. About 68% of the earthquakes are known to originate in the Circum-Pacific belt of folded mountain ranges. Earthquakes are more frequent in Japan and Philippines as these islands have deep trenches on the ocean floor adjoining them. The Mid-world mountain belt which stretches across Europe and Asia is another unstable region which records about 21% of the earthquakes. The remaining epicentres are located in lines of weakness on the ocean floor or deep fractures on the continents or along the coast.

Earthquakes serve the purpose of releasing strains and stresses in the earth's crust caused by both the internal processes and external processes. The formation of folded mountain ranges, the formation of volcanic mountains, the deposition of sediments on the ocean floor disturb the equilibrium and create stresses in the earth's crust. The crust gives way to such stresses after some time resulting in earthquakes. Thus earthquakes help in restoring the equilibrium in the crust.

EXERCISE—4

Short Answer Questions:

1. Describe the composition of the earth's crust.
2. Distinguish between a rock and a mineral.
3. What are igneous rocks ?
4. How are sedimentary rocks formed ?
5. What are fossils ?

6. Distinguish between metamorphic and sedimentary rocks.
7. How are internal processes different from external processes ?
8. Give two examples of landscapes formed by epeirogenic movements.
9. Describe the formation of fold mountains.
10. Distinguish between dormant and extinct volcanoes.
11. What is a seismograph ?
12. Why do earthquakes occur frequently in the recently folded mountain belts ?
13. In what ways has human activity been responsible for causing earthquakes ?
14. How do earthquakes help in restoring equilibrium in the crust ?

Essay Questions :

1. Write a short essay on "Volcanoes".
2. Describe the various processes involved in landscape development.
3. What causes earthquakes ? Describe the effects of earthquakes.

5. Changing Face of the Land—II

The Surface of the land masses is exposed to the action of the externnl processes which take place in the atmosphere, hydrosphere and the biosphere. The changes in weather conditions, such as variation in temperature, action of winds, impact of rainfall, frost action, etc., affects the rocks exposed on the surface of the land. The flow of running water, slow movement of glaciers, the impact of strong waves along the coast are some of processes taking place in the hydrosphere and affecting the surface of the land masses. The presence of vegetation cover, the action of animals and man also have their effect on the landforms seen in an area. Each process or combination of processes produces a distinct assemblage of landforms.

Weathering

We have already seen that the crust of the earth is made up of rocks of various types. These rocks break up spontaneouly when they are exposed to changes in weather conditions. This process of disintegration and decay of rocks is called **weathering**. Weathering may be considered as a process by which rocks adjust themselves to the conditions found on the earth's surface. Such an adjustment becomes necessary as we know that rocks are formed under conditions which are different from those found on the earth's surface.

Weathering breaks up the rocks into smaller and smaller particles which accumulate on the surface as a layer of loose fragments. This layer of weathered particles prevents the underlying rocks from further weathering. This layer of weathered particles is transformed into soil by the action of physical, chemical and biological processes. Thus the processes of weathering help the formation of soils.

The various processes involved in weathering may be divided into two major types: physical weathering and chemical weathering.

Physical weathering refers to the breaking up of the rocks into smaller particles without any change in chemical composition. For example, strong contrasts in temperature between day and night result in successive expansion and contraction of minerals leading to a breaking up of the rocks. Frost action which causes alternate freezing and thawing of water present in the crevises of rocks also leads to mechanical weathering. Chemical weathering is the process by which chemical changes affect the minerals present in the rocks leading to their decomposition and decay. Chemical changes are facilitated by the combination of oxygen, carbon dioxide and water with minerals present in the rocks. Chemical weathering is specially significant in tropical regions with high temperature and heavy rainfall.

The loose fragments of weathered particles accumulated on the land surface do not remain undisturbed for long. They *may get displaced down the slope by the action of gravity.* Such a sudden movement causes landslides and related phenomena. Landslides are specially more frequent on steep slopes after a heavy rainfall. The seepage of rain water through the weathered particles reduces friction leading to their displacement down the slope. Landslides may disrupt road and rail traffic in mountain regions. They may also cause loss of life and property owing to destruction of houses and cultivated lands.

Gradation

Weathered particles accumulated on the surface may be removed by rivers, winds or other agents which move on or over the surface of the land. Weathered particles form the tools for the erosional work of these agents of gradation. **Gradation** involves both **degradation** and **aggradation.** Degradation refers to the processes of erosion which remove the particles from the surface and thus lower the level of the land. Aggradation involves deposition of material brought from elsewhere and this raises the level of the land.

Rivers, glaciers, winds and waves are the main agents of gradation. The agents of gradation generally transport material from highlands to lowlands down the slope of the land and in this process they are aided by the force of gravity. Removal of weathered particles by the agents of gradation leads to the exposure of underlying rock. This process of overall lowering of the land surface by the removal of weathered particles is called denudation.

Denudation

The different agents of gradation do not act uniformly on the surface of the land. The work of running water (streams and rivers) is the most widespread among all the agents of gradation. This is therefore known as the normal process of gradation and is typical of humid regions. In arid regions, such as deserts wind action is dominant. In the absence of vegetation winds may transport readily loose particles of dry sand and dust. The work of glaciers is well developed in polar regions and high mountain regions covered by permanent snow and ice. Wave action is limited to the narrow zone of contact between land and sea. Each one of these agents of gradation produces a distinct variety of landforms.

The landforms developed by an agent of gradation are also related to the time during which the agent has been acting in the area. Three stages—youth, maturity and old age—are usually distinguished in the development of a process of gradation in an area. Youthful stage represents the commencement of the process in an area; mature stage indicates the maximum development of the process and old age refers to the last stage when the area gets reduced to an almost level plain.

Running Water

Running water in the form of numerous streams and rivers is the most important agent of gradation and the landforms produced by running water are widespread in occurrence. Running water derives its energy mainly from the speed with which it moves down the slope. The slope of a river valley decreases

from its source towards its mouth. As the river moves from its source, the volume of water carried, increases gradually by the addition of tributaries. The volume of water is a maximum in the lower course of the river. Rivers transport large quantities of particles derived from weathering and erosion of the land in the river basins. The quantity of land gradually increases from the source towards the mouth. Thus it is seen that the condition governing the work done by running water varies in different parts of the river course.

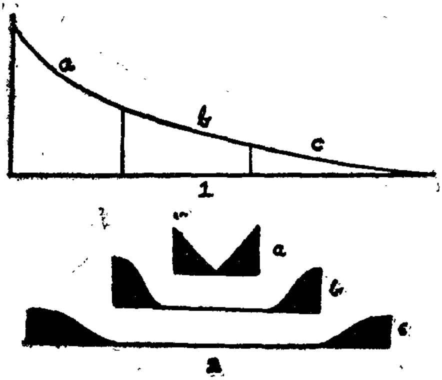


Fig. 5.1

River Course

1. Profile from source to mouth of the river.
a. Upper course b. Middle course c. Lower course.

2. Cross-sections to show form of river valley
(a) upper course - narrow V-shaped valley,
(b) middle course - broad - valley with flood plain
(c) lower course - wide flat plain

At the slope, water supply and load vary along the course of a river; the development of a river valley may be studied by dividing the river course into three sections: the upper course, the middle course and the lower course. The **upper course** of a river is generally found in hilly or mountainous regions. As these regions have steep slope, rivers possess

maximum energy in the upper course. As the load to be transported is a minimum, the river possesses excessive energy over what is needed for moving the load down the valley. This excessive energy is utilised for erosion of the bed of the river. Erosion is mainly accomplished by the strong current of water which loosens rock fragments from the floor and sides of the valley. The impact of these particles of load with the valley also causes erosion.

As erosion is dominant in the upper course, river flows in narrow steep-sided valleys called **gorges**. In course of time, the steep valley sides get weathered and the valley assumes a V-shape. Such **V-shaped valleys** indicate that valley-deepening takes place rapidly in the upper course. Another feature of the upper course is the extension or lengthening of the river course by headward erosion. The source of the river shifts progressively towards the summit. This process also leads to development of tributaries.

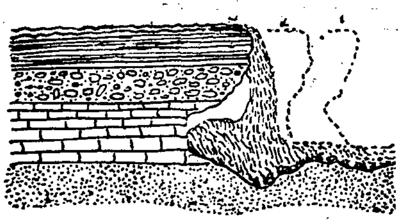


Fig. 5.2

Water Fall

1, 2, 3 represent stages of retreat of the water-fall

[Note the erosion caused at the bottom of the water-fall.]

Water-falls and lakes are typical landforms found in the upper courses of rivers. Water-falls occur in places where the valley has a steep gradient. For example, the Sivasamudram falls on the Cauvery river are located at the edge of the Mysore plateau. Water-falls may also occur due to the exposure of a resistant bed of rock along the valley. The Niagara falls in North America owe their origin to the occurrence of a resistant bed along the valley. Intense erosion at the site of the water-fall may lead to a slow retreat of the site of the fall in an upstream direction. Water-falls are harnessed for generation of hydro-electric power. Lakes occur in the upper course when a river passes through basins or depressions along its path, Lakes regulate the flow of water

in a river. They get gradually silted up by the deposition of sediments. Lakes may be drained away by erosion near the outlet of the lake.

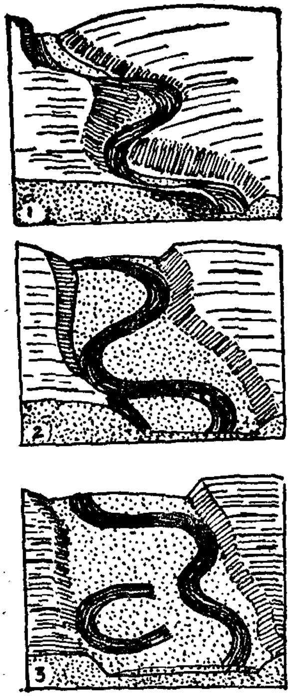
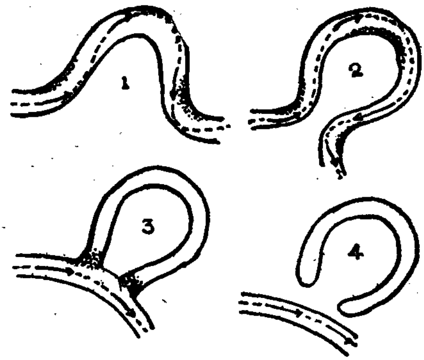


Fig. 5.3
Formation of Flood Plain
1, 2, 3 represent stages of widening of river valley.
[The lake shown in stage 3 is an Ox-bow lake.]

In the **middle course,** as the slope is less than that of the upper course, and as the load is greater than that in the upper course, there is no excessive energy available for deepening of the valley. The valley gets widened partly by weathering of rocks exposed on the valley sides and partly by the impact of load carried by the river with the sides of the valley. A broad relatively flat valley floor is formed with the river channel occupying a part of the floor. Rest of the valley floor is covered by alluvial deposits laid down by the river. Such alluvial deposits on either sides of the river channel constitute the **flood plain.** The sides of the valley assume a gentle slope owing to weathering and movement of material down the slope.

The formation of a broad flood plain along the river course leads to the development of broad sweeping curves in the river channel. Such curves are called **meanders.** Meanders migrate freely down the river valley as the flood plain is broad and flat. Such a migration often leads to cutting off of some meanders through the narrow neck. The river channel follows a straight path, leaving the former meander as a lake. Such lakes are called **ox-bow lakes.**

In the middle course, the river has just sufficient energy to transport the load available in its bed. Neither erosion nor deposition is dominant.



Fig, 5.4

Meanders and Ox-bow Lake

1, 2, 3, 4 represent four stages of the development of meanders. Arrow indicates direction of the flow of river. Ox-bow lake is shown in stage 4.

In the **lower course**, the slope of the river valley is a minimum and the load available in the river is a maximum. The energy available in the river is inadequate to transport all the load and therefore a part of the load gets deposited. Deposition is the most important work done by river in this stage. The flood plain becomes broader and the river flows very slowly owing to gentle gradient. River channel may change its course frequently on the broad flood plain. A part of the load may get deposited along the edges of the river channel forming low embankments. Such natural embankments built by a river in its flood plain are called **levees**.

The deposition of material in the lower course of a river results in the formation of **deltas**. Deltas are triangular shaped tracts of alluvial deposits laid down near the mouth of a river. The base of the triangle faces the sea and the apex of the triangle is inland. The apex of the triangle forms

the head of the delta. From this point onwards, the river develops **distributaries.** The head of the Cauvery delta is located near Tiruchirapalli. Each distributary in turn gets subdivided into smaller and smaller channels and the river

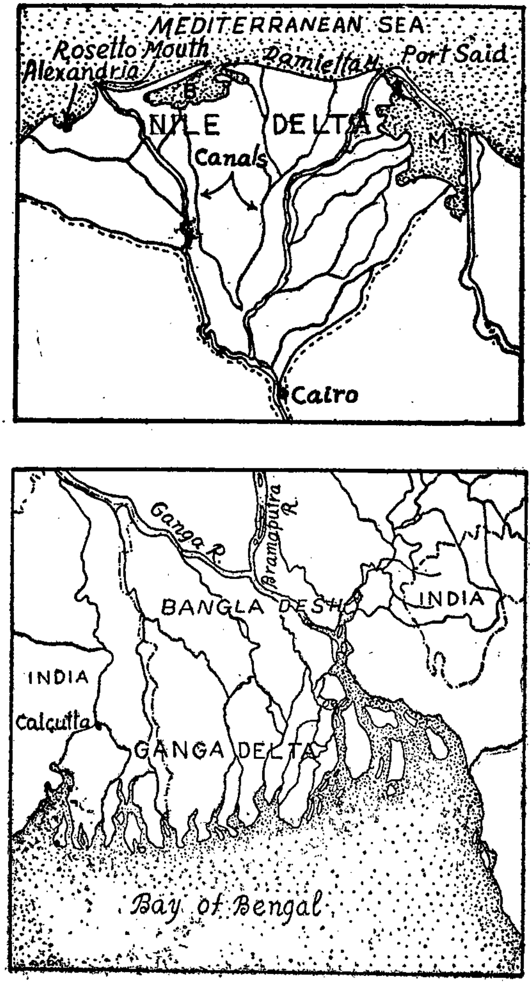


Fig. 5.5

Deltas

[Note the triangular shape of the delta and distributaries]

enters the sea through a number of channels. The formation of distributaries spreads the alluvial deposits over a large area. Deltas of rivers may contain many abandoned river channels in the form of lakes. Deltas are well developed in rivers which carry large quantities of sediments and have a long lower course with gentle gradient.

Large rivers like the Amazon carry large quantities of load, which may exceed one million tonnes per day. Such rivers have huge capacity to wear down land masses. The work of rivers tends to reduce the irregularities in the surface of the land It is considered that in the final stage an almost level plain may be formed. Such a plain is called the **peneplain.** It is estimated that at the present rate of erosion of the land, entire United States would be worn down to a level plain near sea level in a period of about 12 million years.

Glaciers

Glaciers are moving masses of snow and ice. They occur mainly in high latitudes such as the polar regions and high altitudes, namely mountain ranges. All mountain ranges do not have glaciers. Only those mountain ranges, whose peaks have a permanent cover of snow and ice, have glaciers. The height above which there is permanent cover of snow and ice is known as the **snow-line.** The height of the snow line decreases from a height of 5,500 metres at the equatorial regions to sea level in the polar regions. In the Himalayas the height of the snow line varies from 4,200 to 5,500 metres depending on the amount of snow fall.

Glaciers may be classified into two broad types: **Continental glaciers** and **Valley glaciers.** Continental glaciers are vast ice sheets of great thickness covering the surface of the land almost completely. For example, the continent of Antarctica is covered by a thick ice sheet. Such ice sheets were more extensive in the geological past. For example, about one million years ago, ice sheets covered northern half of North America and most parts of North-Western Europe.

Valley glaciers are found in mountain regions such as the Alps or Himalayas. These glaciers are also known as mountain

or Alpine glaciers. They extend along the valleys as tongues of ice. They originate in snow fields covering the peaks of mountain ranges. Valley glaciers are small in size, both in terms of thickness and length. The maximum length of a valley glacier in the Alps is only 16 Km. In the Himalayas, valley glaciers extend upto a length of 100 Km. They melt away along their edges and many of the Himalayan rivers orginate from valley glaciers.

Glaciers move at an average rate of a few metres per day as their movement is retarded by friction with the floor. Therefore, glaciers do not erode the land in the same manner as a swiftly flowing river. Particles of rocks which are embedded in the glacier, erode the floor on which the glacier moves. Glaciers also pluck away particles of rocks from the floor and sides of the valley as they move slowly. Glacial erosion is not uniformly the same everywhere. Glacial erosion may lead to the formation of depressions or basins of varying sizes.

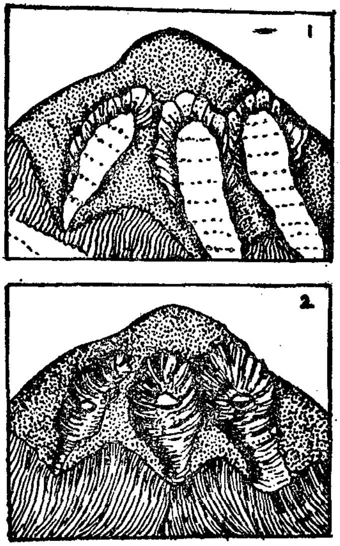


Fig 5.6
Cirques
1. During glacial period cirques are covered by ice.
2. After glaciers melt away, cirques contain small lakes.

As large parts of North America and Europe which were occupied by glaciers in the geologically recent period are now free from glaciers; it is now possible to study the landforms which were formed by glaciers in the past. In regions of alpine glaciation, the most typical landforms are cirque, U-shaped valley and hanging valley. In areas covered by continental glaciers an almost featureless surface with depressions of varying sizes is formed as seen in parts of Canada and Scandinavia.

Cirques are nearly circular depressions with a flat floor and steep slopes on all sides. These are found near the summits of mountain regions. In these regions snowfall is heavy and snow accumulates in scattered depressions. In course of time the snow is converted to ice because of pressure. Alternate freezing and melting of water in the crevises and joints of rocks leads to breaking up of rocks on the margins of the snow fields. Small depressions thus get enlarged and become circular in shape. Most of the valley glaciers originate from cirques and move along the pre-existing river valleys.

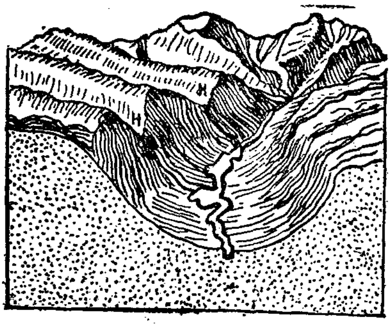


Fig. 5.7

U-shaped Valley and Hanging Valley

The main valley is a U-shaped valley. H-indicates hanging valley.

[Note the flat floor and steep-sides of the U-shaped valley.]

The narrow V-shaped river valleys are unable to accommodate the large volume of glaciers which flow through them. Glaciers overflow on either side of the valleys. The movement of the glacier with large quantities of rock particles embedded at the bottom, along the valley leads to widening of the V-shaped valley into a U shaped valley. The U-shaped valley has a broad flat floor and steep sides. While the cirque is typical of the summit regions, the U-shaped valleys occur in the lower slopes of mountain regions.

In glaciated mountain regions, valleys of tributary glaciers are not deepened to the same extent as the valley of the main glacier. As the glaciers have a large volume, tributary glaciers will meet the main glacier at the same level. After the glaciers melt away, the tributary valley appears to hang abruptly. Streams flowing in such tributary valleys join the main valley through waterfalls.

When glaciers melt, all the particles carried by the glacier get deposited to form an irregular heap of materials of all size; such deposits are called **moraines.** Deposits which accumulate along the edge of a glacier are called terminal moraines. Lateral moraines are deposited along the sides of valley glaciers. Rivers originating from melting of glaciers carry large quantities of fine rock dust produced by grinding action of glaciers. This gets deposited along the valley and such deposits are called **boulder clay.**

Winds

Wind as an agent of landscape formation is specially significant in desert regions, though its action may be present in other regions also. Wind acts as an erosive agent only when it transports large quantities of sand. The erosive action of winds acts just similar to sand blast action. The absence of vegetation permits the wind to blow freely near the surface of the land. The capacity of winds to transport material reaches a maximum during dust storms. While dust may be transported in suspension to great heights, sand particles are carried in the lower layers of the atmosphere upto a height of a few metres above the ground. Erosion by wind action is restricted to the height upto which sand is transported.

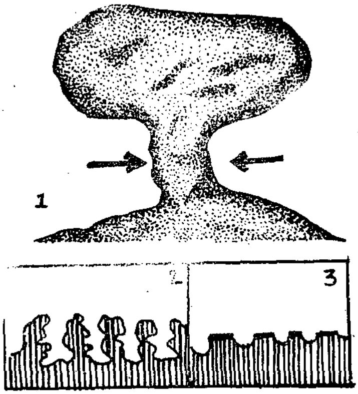


Fig. 5.8

Features of Wind Erosion

1. Mushroom rock-Arrow indicates level of maximum wind erosion 2. Yardang 3. Zeugen.

Mush-room rock is a typical landform produced by wind erosion. This has the shape of a mushroom with a

broad top and a narrow trunk. The narrow trunk portion indicates maximum erosive action by winds. The erosive action is less near the ground owing to friction and at levels above the trunk, sand transported by wind is much reduced. **Yardang** and **Zeugen** are other minor landforms produced by wind erosion.

The material carried by winds is deposited when its velocity is reduced or when there is some obstruction in the path of the wind. **Sand dunes** and **loess** deposits are the main features of deposition. Sand dunes may assume different shapes and sizes. The most common type of sand dune is called the crescentic dune or **barchan.** Such dunes are deposited at right angles to the direction of winds. The horns of the crescent extend in the direction of winds. The height of dune may not exceed 30 metres and maximum width may be about 400 metres in the centre. Both width and height decrease towards the tapering horns of the crescent. These dunes migrate gradually in the direction of winds. Sand dunes which are deposited parallel to the direction of winds are called longitudinal self dunes.

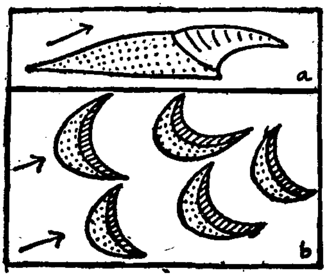


Fig. 5.9

Barchan

a) Cross-section indicates contrast in slope clearly.
b) Note the location of barchans at right angles to the direction of winds.

Extensive deposits of dust are laid down by winds along the margins of deserts. Dust particles remain suspended in the air and get transported over long distances. They settle down when there is rainfall. These wind blown deposits are known as loess. They are well developed in North-west China. In this region loess deposits cover the entire surface of the land and maximum thickness may be a few hundred metres. Soils derived from the erosion of loess deposits are very fertile.

In semi-arid regions, the action of winds is supplemented by that of running water in the rainy seasons. Running water helps in the transport of weathered material down the slope, though the streams are non-perennial. **Pediment** is a typical landform in such regions. Pediments are extensive surfaces having a gentle slope. They occur in foot-hill regions in striking contrast to the steep slopes of the hills. Isolated hills which rise steeply from relatively level surface of the pediments are called **inselbergs**.

Waves

The action of waves as agents of landscape formation is seen in the zone of contact between land and sea. Wave action is governed by the nature of waves, the slope of the shoreline, and the types of rocks exposed along the shore. Waves in the ocean are primarily driven by winds. As these waves travel towards the shore, their progress is retarded by the shallow sea near the shore. The crest of the wave moves forward and breaks with great force. Such breaking of the wave causes erosion of the land along the shore. As the waves move backwards, the eroded material is transported and deposition may take place on the sea floor or at any point along the shore. Thus wave action involves erosion, transportation and deposition.

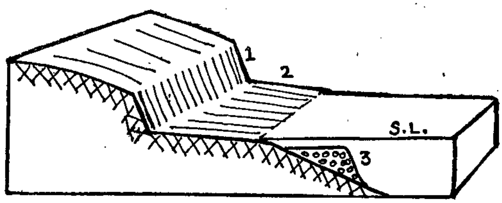


Fig. 5.10

Wave Erosion

1. Cliffs 2. Wave-cut platform 3. Wave-built terrace formed by deposition below sea-level

The most typical landform produced by wave erosion is the **cliff**, a steep slope facing the sea. Cliffs are well developed in shorelines having a steep slope. Cliffs are gradually pushed backwards by continuous wave erosion. The height of cliff also increases. The retreat of cliffs inland leaves a relatively flat **wave cut platform** at the base of the cliff. Cliffs are well developed in regions of hard rocks.

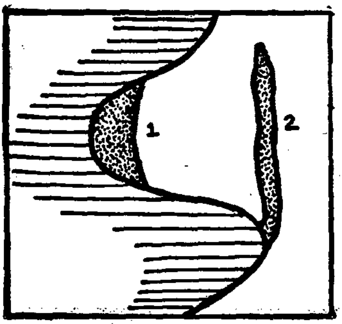


Fig. 5.11

Wave Deposition

1. Beach along the Bay
2. Sand bar

Deposition of material by waves leads to the formation of **beaches** along the shore. Such deposits are more extensive in shallow sheltered waters of the bays. Beaches may contain sand or gravel or pebbles in varying proportions. Beaches are extensive along shorelines having gentle slope.

Sand and gravel may get deposited parallel to the shore to form an embankment or **sand bar**. In course of time such bars may grow in size. The shallow sea between the sand bar and the shore becomes a shallow lagoon. The shallow backwaters of Kerala are of such origin. **Spits** are sand bars which extend from the shore.

The nature of shoreline in an area depends on several factors such as recent changes in sea level or earth movements. For example, when sea level rises, a part of the land gets submerged and the shore line becomes irregular in outline. Such a shoreline is called a **shoreline of submergence.** Such a shoreline will have headlands projecting into the sea and bays alternating with each other. Shoreline of submergence may also be formed by subsidence of land without any change in sea level. In shorelines of submergence, wave erosion is concentrated in the headlands leading to the formation of

cliffs; beaches are formed in the bays. The west coast of India south of Bombay is a good example of a shoreline of submergence.

When sea level falls or land is uplifted along the shore, a part of the former sea floor is exposed. Such a shoreline is called a **shoreline of emergence.** Such a shoreline has a gentle slope and therefore wave erosion is a minimum. Depositional features like sand bars, spits, lagoons and marshes are common. Kerala coast has features of emergent shoreline.

Compound shorelines are those which are affected by both emergence and submergence alternatingly. Neutral shorelines are those whose features are not related to changes in sea level. Shorelines of volcanoes are an example of neutral shoreline.

Concept of Balance or Equilibrium

We have seen that two sets of forces are at work in carving out the various landforms. The internal or tectonic forces are generally constructive in nature as they result in uplift of land to form huge mountains, extensive plateaus or volcanic mountains. The external or gradational processes tend to reduce the differences in elevation and bring about a gradual flattening of the land surface. These two sets of forces are complimentary to one another. If the internal forces do not operate, the land surface would have been reduced to a flat level plain. If the denudational forces

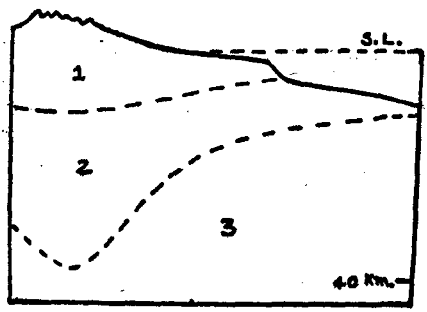


Fig. 5.12

Isostasy

1. Sial layer 2. Sima layer 3. Mantle.

[Note that the lighter continent is floating on the denser layer below.]

do not operate, there would be greater irregularities on the land surface and level plains would have been absent. These two forces are in a state of balance or equilibrium.

When the gradational processes transport large quantities of material from the land to the sea, the balance is disturbed. The balance is also disturbed when volcanoes pile up huge quantities of lava. Similarly, the accumulation of ice sheets on land masses increases the mass and disturbs the balance in the crust. The State of balance or equilibrium in the crust is called **isostasy.** Whenever the balance is disturbed, crustal movements or flowage of matter below the crust takes place to restore the balance or equilibrium. Stresses and strains built up in the crust of the earth are relieved by sudden earth movements which bring about earthquakes.

As the continental blocks are made up of lighter sial, they may be considered as floating on denser sima layer below them. When mountain ranges get denuded by gradational processes their mass gets reduced and therefore, they get uplifted gradually by force of buoyancy in the same manner as a ship whose load is reduced. The accumulation of ice sheets leads to a depression of the land masses. When the ice sheets melt away, there is a gradual uplift of the landmass. This has been observed in Scandinavia. Such movements of the earth's crust are called **isostatic movements.**

EXERCISE—5

Short Answer Questions :

1. What is meant by weathering?
2. Distinguish between physical weathering and chemical weathering.
3. Give an example of physical weathering.
4. How are landslides caused?

5. Distinguish between degradation and aggradation.
6. What is denudation?
7. Describe the slope, volume of water and load vary along the course of a river.
8. How are flood plains formed?
9. What are meanders?
10. Describe the work done by a river in its lower course.
11. Write a short note on "delta".
12. Distinguish between continental and valley glaciers.
13. How are cirques formed?
14. What are moraines?
15. Name the landforms produced by wind erosion.
16. Describe barchans.
17. What is a shoreline of submergence?
18. What is meant by isostasy?

Essay Questions :

1. Describe the main features of the upper course of a river.
2. Bring out clearly the contrasts in the work done by a river in its upper, middle and lower courses.
3. Describe the landscape features formed by glaciers in mountain regions.
4. Give an account of the landforms produced by waves.
5. Discuss the concept of balance of equilibrium.

6. Hydrosphere — I

The hydrosphere includes oceans, seas, lakes, rivers, glaciers and other bodies of water on the earth's surface, as also underground water and water vapour in the atmosphere. Water is also present in the organisms which live on the earth. As the earth is the only planet in the solar system which has abundant quantities of water, it is known as **the watery planet**. The oceans comprise 71% of the surface area of the earth. The hydrosphere is an important element of the physical environment of the earth.

Importance of Water

The availability of abundant quantities of water on the earth is responsible for the growth and development of all living organisms on the earth. Water is necessary to sustain all types of human activities. Agriculture depends on rainfall which may be supplemented by irrigation from rivers or other sources. The spread of irrigation has helped to bring new lands under cultivation and has led to increase in yields. Pastoral activity is also related to water supply for domestic animals.

Large quantities of water are needed for industries such as iron and steel, paper, textiles, chemicals. etc. The flow of water in rivers has been harnessed by man to generate electricity. Perennial rivers having steep gradients and water-falls along their courses are suitable for power generation. Sivasamudram falls on the Cauvery river have been harnessed for generation of electricity.

Water is also useful for navigation. International trade is made possible by the development of sea routes. Large ships transport huge quantities of cargo at relatively cheap

cost. Rivers, canals and lakes are used for navigation inland from the coast. The Soviet Union has a network of inland waterways which link major river systems and the adjoining seas.

Large quantities of water are needed for domestic needs such as drinking, cooking, washing, bathing and disposal of sewage and wastes. Protected water supply is not yet readily available in rural areas. Villagers sometimes walk more than 1 Km to get drinking water. Provision of water supply to large cities is becoming more costly and difficult. Urban water supply has to serve the needs of industries located in cities. Water is also used for recreation such as swimming and boating. Water bodies such as seas, lakes and rivers are used for fishing.

Too much of water during floods and too little of water during droughts cause large scale destruction and misery. Floods submerge extensive lowlands in the valleys and deltas of rivers resulting in considerable damage to life and property. Successive years of drought in an area may lead to famine conditions. While some parts of Cauvery valley and delta are subject to floods, parts of Dharmapuri and Ramanathapuram districts are liable to droughts.

As water is essential for man and his activities, it is desirable to plan the development and use of water resources available in an area. Multipurpose projects serve the purpose of controlling floods, irrigation, generation of power, navigation and water supply to cities and industries. For example, the Damodar Valley Project is a multipurpose project. Such careful planning of water resources is necessary as the available supplies are limited and demand for water is gradually increasing in both rural and urban areas.

Sources of Water

The total quantity of water available in the world has been estimated at about 1,360 million cu.km. This includes water in solid, liquid and gaseous states. Of this, the oceans and adjoining seas contain 1,322 million cu. km. or 97%. This

WATER RESOURCES OF THE WORLD

Location	Volume of Water in mill. cu. km.	Percent of total
Oceans	1,322.000	97.200
Ice caps & glaciers	29.200	2.157
Sub-Surface water	8.407	0.625
Surface water (rivers & lakes)	0.23	0.017
Atmosphere	0.013	0.001
Total	1,359.850	100.000

Table 6.1

large quantity of water is not of much use owing to its salt content. Water occurs on the land both in solid and liquid forms. Ice caps and glaciers which are found in polar regions such as Antarctica and Greenland and high mountain regions such as the Himalayas, contain 29.2 million cu. km. of water. Though this is only 2.15% of total water in the hydrosphere, it forms 75% of all fresh water available. Ice caps and glaciers have not been utilised by man as sources of water to any great extent.

Lakes and rivers provide major share of fresh water used by man. Water available from such water bodies amounts to only 0.23 million cu. km. In some places, this is supplemented by ground water stored in surface layers of rocks. Moisture present in the soil layer is useful for plant growth. Water available in ground water storage is nearly 40 times that of available from lakes and rivers. The total quantity available is estimated at 8.4 million cu. km. Of this quantity only about half is located within a depth of 0.8 km and is thus more readily accessible than water located at greater depths.

Though extremely small quantities of water are present in the atmosphere in the form of water vapour, it is of much greater significance. On an average the atmosphere is estimated to contain 0.013 million cu. km. (0.001 % of total) of water vapour. Precipitation of water from the atmosphere in the form of rainfall, snow fall and other minor forms is the main source of fresh water on the land. The usable reserve of accessible fresh water derived from precipitation, surface run-off and storage and ground water is indeed quite limited.

Hydrological Cycle

Water present in the oceans, on the land and in the atmosphere is in constant state of movement, though some parts of it may be stored for some time in lakes and glaciers. Water flows on the land in the form of numerous streams and rivers. In the oceans, waves, tides and ocean currents transport huge quantities of water over great distances. Water vapour present in the atmosphere is transported by winds.

Water moves not only within each medium, but also from one medium to another. For example, evaporation of water from the oceans results in the transfer of water from the oceans to the atmosphere. Rivers help in moving water from land to the oceans. Precipitation from the atmosphere adds water to the surface of the lands and oceans. Water may seep below the surface and later reappear in the form of springs at a different place. Water present in the soil layer may be absorbed by the plants and given off from the leaves during transpiration.

These movements of water between land, sea and air may be considered in terms of a continuous cycle, called the **Hydrological Cycle**. Though the cycle is extremely complex in nature, a simple cycle consists of three sections. The first involves evaporation of water from the oceans leading to addition of water vapour to the atmosphere. Winds transport such moist air towards land masses and a part of the water vapour may get precipitated on the land. The final section consists of the flow of water from the land back to the oceans through rivers. This simple cycle gets modified

when water gets stored on the land in the form of ice sheets and glaciers or lakes. Water may also get stored in the soil or as ground water in the rock layers. Water stored in the glaciers enters the hydrological cycle when the ice melts. The action of living organisms such as plants and animals also affects the movement of water through the cycle.

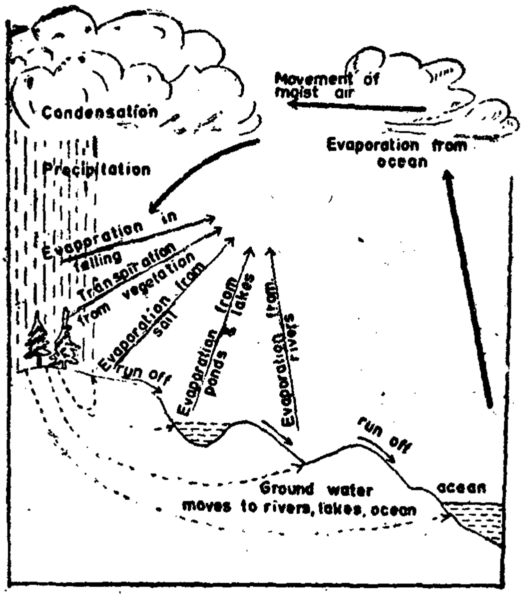


Fig. 6.1

Hydrological Cycle

[Note the various processes involved in the hydrological cycle.]

The movement of water through the hydrological cycle involves change of state also besides change of medium. The temperature in the earth is such that water may exist in solid, liquid and gaseous states. While bulk of the water is in liquid state, addition of heat energy leads to evaporation and conversion to water vapour. About 600 calories of heat are needed to evaporate one gram of water into vapour. Coll-

ing of water below freezing point leads to formation of ice. When temperature rises above freezing point ice may melt. Such changes in physical states help ready circulation of water.

The hydrological cycle helps to maintain a state of balance or equilibrium between the three media through which water is moving. It is estimated that 517,000 cu. km. of water are evaporated from sea and land put together. This enters the atmosphere and gets precipitated partly on the land and on the seas. There is a balance between the amount of water entering the atmosphere by evaporation and the amount lost by precipitation. On land, the amount of precipitation received (108,000 cu. km) is greater than the amount of water evaporated (62,000 cu. km.) The surplus represents the quantity flowing on the surface and below the surface of the land and finally entering the seas. The flow of water from the land to the sea compensates for the excess of evaporation over precipitation on the oceans. This means the quantity of water in the oceans remains almost constant. Though there is an overall balance in the quantity of water, there may be periods of excess or deficit, if one considers particular areas and not the world as a whole.

Oceans and Continents

The primary contrast on the surface of the earth is between the vast oceans which form a continuous body of water and the continents which rise above them as islands. The distribution of continents and oceans is uneven. Though the total area of the continents is only 29% of the surface area of the earth, the Northern hemisphere has a greater percentage (39%) of land than the Southern hemisphere (19%).

Scientists consider that the distribution of continents and oceans has been different during the long history of the earth. It is believed that there was a single large continent and it broke apart and drifted in different directions to produce the present pattern. There is increasing evidence to support this theory of continental drift. Recent studies have indicated that the earth's crust consists of about six major plates and some minor plates which drift on the surface. The boundaries of

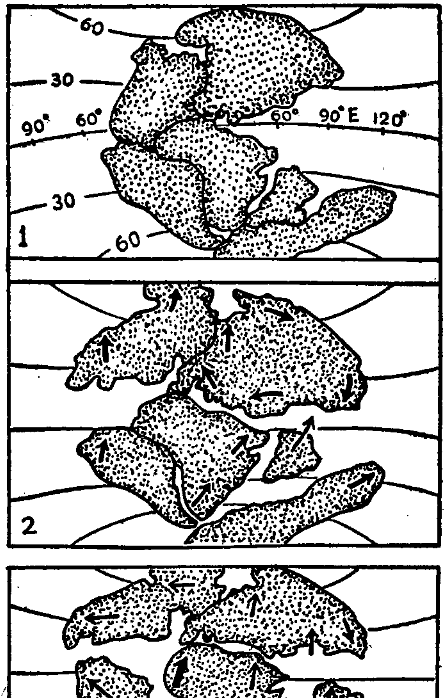


Fig. 6.2

Continental Drift

The three maps show the positions of continent in different periods. Arrows indicate the direction of movement.

1. 325 million years ago 2. 135 million years ago
3. 65 million years ago

these plates are zones of weakness in which volcanic eruption and earthquakes occur. The formation of folded mountain ranges and the mid-oceanic ridges are also related to movements of plates.

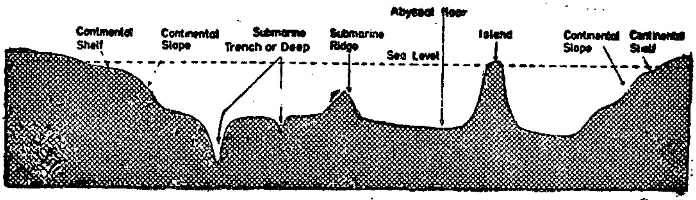


Fig. 6.3

Features of the Ocean Floor

[Note that the ocean floor is not a smooth plain]

The contrast between continents and oceans is not merely in their relative levels. They are structurally different. Continents are made up of lighter sialic layer while the oceans consist of denser sima layer. The lighter continents may be considered as floating on the sima layer below them. The edge of the continental block is marked by a steep slope called the continental slope. Between the continental slope and the shore is a shallow sea formed by submergence of a portion of the continental block. This shallow sea floor is called the continental shelf. The continental shelf has a depth of less than 180 metres and its width may vary from a few kilometres to 100 km. Continental shelves may have valuable reserves of petroleum. Rich fishing grounds are located on continental shelves.

Beyond the continental slope lies a vast undulating ocean floor known as the abyssal plain. The depth of the abyssal plain may vary from 3600 to 5500 metres. While submarine ridges, plateaus and volcanic cones rise from the ocean floor, there may also be narrow trenches having depths exceeding 8000 metres. Relief features of the ocean floor are more diversified than those on the continents.

World's Major Oceans and Seas

The Pacific ocean is the largest ocean having an area exceeding that of all land masses. It extends from Bering Strait in the north to the Antarctic continent in the south covering a distance of about 15,000 km. The width of the Pacific ocean along the Equator exceeds 16,000 km The continents of North America and South America are situated east of the Pacific ocean while to the west lie the continents of Asia and Australia. The narrow Bering Strait in the north links the Pacific ocean with the Arctic ocean. Several narrow straits between the islands of Indonesia link the Pacific ocean with the Indian ocean.

Recently folded mountain ranges and active volcanoes are found along the coast of the Pacific ocean. The Rockies of North America and the Andes of South America rise steeply from the Pacific coast. On the western margins of the Pacific ocean are a series of island arcs from the Aleutian islands to New Zealand. The island arc are bordered by deep oceanic trenches such as Japan trench, Mariana trench, etc. Between the island arcs and the mainland of Asia are located marginal seas such as the Sea of Japan, East China sea, and South China Sea. Besides the island arcs off the coast of Asia, there are a number of islands. Some of these such as those of Hawaii are of volcanic origin; others such as the Marshall islands are of coral origin.

The Atlantic ocean covers half the extent of the Pacific ocean. But owing to the irregular coastline of the bordering land masses, the length of the coastline exceeds those of the Indian and Pacific oceans put together. The ocean is S-shaped with a width of only 2600 km. at the Equator. The width increases to 4800 km. at 40°N and to 5900 km. at 35°S. While the Atlantic Ocean opens widely towards the south and links with the Pacific and Indian oceans, only narrow straits between islands link this ocean with the Arctic ocean in the north.

The most prominent feature of the Atlantic Ocean is the Mid-Atlantic submarine ridge which lies almost equi-

distant from the east and west coasts. There are extensive continental shelves off the coasts of Western Europe and northeastern North America. Trenches are few unlike in the Pacific ocean. British Isles and Newfoundland are continental islands which rise from the continental shelf. The islands of West Indies form an island arc. There are very few islands away from the coast.

North Atlantic ocean contains many marginal seas, Some of these seas such as the Baltic Sea, North Sea. Hudson Bay and Baffin Bay are shallow seas with depth less than 180 metres. The Mediterranean Sea, The Gulf of Mexico and the Caribbean Sea are deep ocean basins with depths exceeding 3000 metres.

The **Indian ocean** extends just beyond the Tropic of Cancer, as it is enclosed by the peninsulas of South Asia on the northern side. On the western side lies the continent of Africa; the continent of Australia is located on the east. The northern part of the Indian ocean is divided by the Indian peninsula into the Arabian sea and the Bay of Bengal. The Red sea and the Persian Gulf are marginal seas. The ocean opens widely towards the south and links with the Atlantic and Pacific oceans.

A prominent Mid-Indian submarine ridge extends southwards from Lakshadweep islands to Antarctic continent.- East of this ridge is a vast basin, while to the west lie a number of minor ridges and basins. Among the main islands are Malagasy, Sri Lanka and Sumatra and Java which form a part of the island arc of Indonesia. The deepest part of the Indian ocean is in the Sunda trench south of Java. The Andaman and Nicobar islands of the Bay of Bengal represent a continuation of the Arakan Yoma ranges as submerged folded mountains. Lakshadweep and Maldive islands are of coral origin. Mauritius and Reunion are volcanic islands.

The **Arctic Ocean** is the smallest ocean having an area of 15 million sq. km. It is circular in shape and is almost completely surrounded by land masses. Narrow straits such as

the Bering strait and Davis strait link the Arctic ocean with the Pacific and Atlantic oceans respectively. Most parts of the Arctic ocean remain permanently frozen. There are shallow marginal seas such as the Barents sea, Beaufort sea etc., along the margins of the Arctic ocean. There are also a number of islands along the margins of the ocean.

Ocean Waters

We have seen earlier that the oceans contain about 97% of all water available on this planet. The waters of the oceans are saline and therefore they are not directly used by man except for the manufacture of salts. The average quantity of salts dissolved in sea water is 35 grams per 1000 grams. The salinity of sea water is expressed as 35‰. (35 per thousand). This means if 1000 grams of sea water is evaporated, it will yield 35 grams of salts on an average. Sodium chloride alone accounts for 78% of the total quantity of salts present. The other salts are magnesium chloride, sodium sulphate, calcium chloride, potassium chloride and etc. Traces of about half of the known elements are found dissolved in sea water.

The composition of sea water is different from that of river water. River water has abundance of calcium salts, especially calcium carbonate. Thus the composition of sea water cannot be explained by assuming that all salts in the sea are derived from dissolved salts present in rivers which add them to the seas and oceans. The quantity of salts contributed by rivers to the oceans is quite small compared to the total quantity of salts present in them. It is more likely that the waters of the oceans and their salt content are derived from volcanic eruptions in which steam and other gases are released. This explains the abundance of chloride in sea water. The calcium carbonate added by river waters is utilised by marine organisms to form their shells and bones.

Owing to intense mixing caused by movements of sea water the relative proportion of salts remains constant. The total quantity of salts dissolved in sea water does not increaes

in course of time even though rivers are adding salts dissolved in their waters. This is because salts are deposited on the ocean floor. Thus a balance is maintained between salts added and salts precipitated on the ocean floors.

Salinity of sea water shows minor variations from the average value of 35‰. Addition of fresh water from rainfall or from large rivers decreases salinity. Thus in the equatorial regions salinity is lower than average owing to heavy rainfall. Salinity is also reduced by the addition of fresh water by the melting of ice sheets and glaciers. This explains the low salinity of Polar seas. In the sub-tropical regions, intense evaporation due to high temperature and strong winds leads to an increase in salinity. Such sub-tropical seas have salinity exceeding 37‰.

Salinity of water in the marginal seas shows wide variation because there is no free mixing with waters of the adjoining oceans. Thus the Baltic sea and the Black sea have low salinities of 7‰ and 18‰ respectively owing to addition of fresh water from rivers and low evaporation. The Mediterranean sea and the Red Sea have salinities exceeding 40‰ in some portions owing to low rainfall and high evaporation. Inland seas such as the Dead Sea (250‰) and Caspian Sea (180‰) have extremely high salinities. The Sambhar lake in Rajasthan has high salinity.

Circulation of Ocean Waters

Waters of the oceans are in a constant state of movement. Such mevements are produced by the force of winds blowing on the surface of the ocean, gravitational forces of the sun and moon causing tides, and density differences. There are horizontal and vertical currents which lead to transport of large masses of water from one place to another and also sinking and upwelling. The most obvious of such movements are the surface currents.

The surface currents of the oceans are primarily caused by the frictional effect of prevailing winds on the ocean waters. The pattern of surface currents shows a close

relation with the pattern of major wind belts. The direction of these currents is slightly modified by the shape of land masses. Rotation of the earth causes a deflection of ocean currents to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

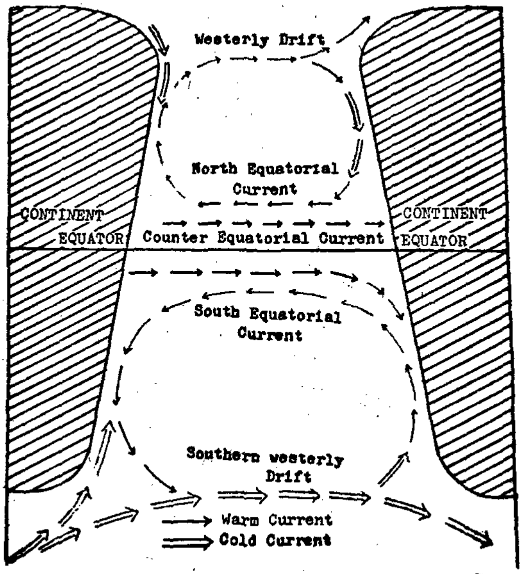


Fig. 6.4

General Sketch of Ocean Currents

[Note the clockwise circulation in the Northern Hemisphere and anti clockwise circulation in Southern Hemisphere.]

In the Tropical regions of the oceans, the surface currents flow from east to west owing to the effect of the Trade winds. In the Temperate regions, the surface currents flow from west to east due to the Westerly winds. Thus there is a clockwise circulation of surface currents in the Northern Hemisphere and anti-clockwise circulation in the Southern Hemisphere.

Ocean currents, which move polewards from tropical latitudes are warm currents, because their temperature is greater than those of the oceans into which they are moving. Warm currents carry the warmth of the tropics to the middle and high latitudes. Cool currents are those which move equatorward from middle and high latitudes. These currents are cooler than the surrounding ocean waters. Cool currents found along the western margins of continents in the tropical belt owe their low temperature to the upwelling of cold water from lower levels to the surface. Cool currents in latitudes beyond 40° are found along the eastern coasts of continents. These currents originate from the melting of glaciers of Polar regions.

Study the map of ocean currents and name the warm currents and cool currents. In the north Atlantic ocean, the Gulf Stream and its continuation the North Atlantic Drift are warm currents. The Canaries current along the west coast of Sahara desert in Africa is an example of a cool current formed by upwelling of cold water. The Labrador current on the east coast of Canada is an example of cool current originating from the Polar region.

While the Atlantic and Pacific oceans conform to the general pattern described, the northern part of the Indian ocean is an exception. The surface currents of the Arabian Sea and the Bay of Bengal are affected by the monsoon winds and therefore the direction of currents also gets reversed.

Importance of Ocean Currents

Ocean currents transport huge quantities of water over distances and this helps in the transfer of heat from low latitudes to middle and high latitudes. In this respect, the circulation of ocean waters plays a role similar to that of atmospheric circulation. The effect of ocean currents in modifying the climate of adjoining land masses is specially significant only when winds blow from sea to land. Such onshore winds transport the warmth of ocean to great distances inland.

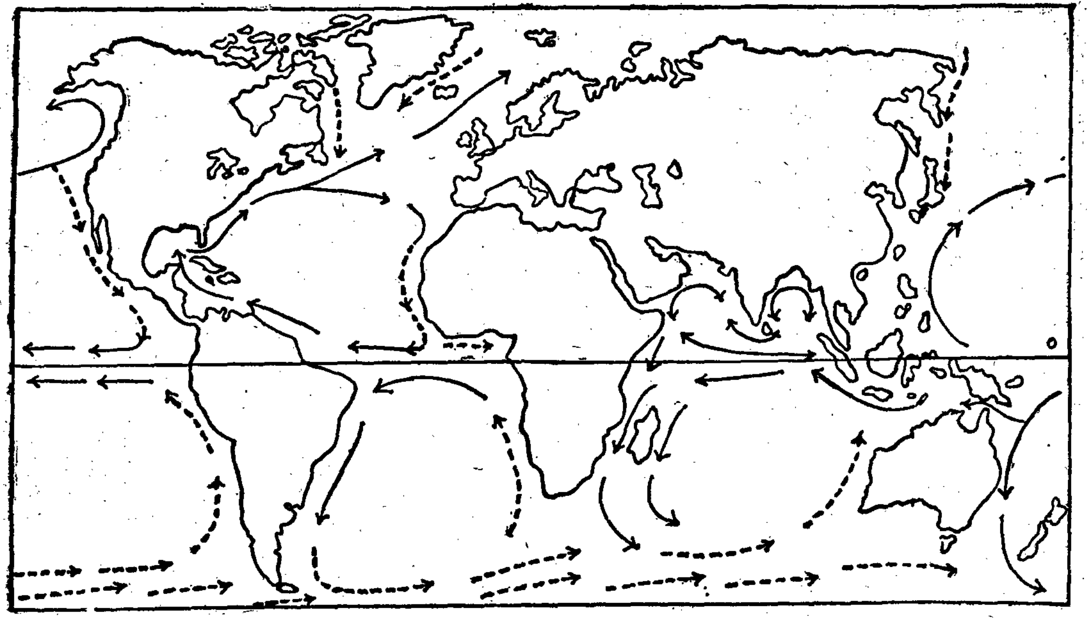


Fig. 6.5

Map of Ocean Currents

Continuous lines show warm currents. Dashed lines show cool currents.

For example, the warm Gulf stream and its continuation the North Atlantic Drift transport warm waters to middle and high latitudes along the west coast of Europe. Owing to this warmth the harbours of Western Europe remain free from ice even upto the Arctic circle, while on the east coast of North America, harbours are not open for navigation even in 40° latitude. The prevailing Westerly winds transport the warmth of the ocean far inland as there are no mountain ranges in north-south direction across the path of winds as in the west coast of North America. Most parts of Western Europe are warmer than the average for these latitudes during winter, owing to the Westerly winds blowing from the warm North Atlantic Ocean.

On the east coast of North America in latitudes beyon 40° North, cool Labrador current flows along the coast. As the winds blow away from the shore, the effect of cool currents is not felt inland from the coast. But the coastal region has lower than average temperature and the ports get frozen in winter. Thus in the middle and high latitudes, ocean currents are responsible for cooler conditions on the east coasts of continents, and warmer conditions on the west coasts.

In the subtropical latitudes, cool currents prevail on the western margins of continents and warm currents flow on the eastern margins. For example, the cool California current on the west coast of the United States causes fogs and also reduces the temperature during summer. Study the map of ocean currents and name currents similar to the California current. The effect of warm current in the east coast of subtropical regions is not significant because, the land itself is warmer in summer.

Besides modifying the climate of the coastal regions, ocean currents are of great significance in relation to fishing. In the regions of cool ocean currents of the sub-tropical regions, upwelling of water from great depth brings nutrients to the surface waters. Abundance of nutrients leads to rich marine life. The cool ocean current along the coast of Peru forms a rich fishing ground. In the middle latitudes warm ocean currents and cool currents converge along the east

coast of continents between 40° and 50° latitudes. Such regions are rich fishing grounds. The seas around New Foundland and Japan are examples of fishing grounds located in the zones of convergence of warm and cool currents.

Changes in Sea Level

Though there is an overall balance in the quantity of water present in the oceans, the land masses and the atmosphere, the sea level does not remain constant. There are evidences to indicate that sea level has changed from the past. Raised beaches a few metres above the present level of the sea represent a former period of higher sea level. A recent rise in sea level on the other hand, leads to submergence of shoreline leading to the formation of an irregular shoreline with wide estuaries. The identification of submerged forests along the coast of Bombay indicates that the sea level has risen recently. Changes in sea level show both short term and long term trends.

World-wide changes in sea level are partly related to changes in temperature of the atmosphere. If temperature goes on decreasing continuously over a number of years, the quantity of snowfall increases and ice sheets and glaciers become more extensive. Such a period is known as a glacial period. As snow accumulates on the land and does not flow rapidly to the sea like rivers, there is a fall in sea level. A glacial period may be followed by a period of increasing warmth during which glaciers melt and this causes rise in sea level.

Changes in sea level may also be produced by earth movements. For example when there is a local uplift of land along the coast, a part of the ocean floor becomes the new shoreline and the sea level appears to have fallen. When there is subsidence of land along the coast, the resulting shoreline resembles one produced by a rise in sea level. These earth movements affect small areas only.

Sea level may also be altered when there are earth movements along the ocean floor. The formation of

submarine ridges and the eruption of volcanoes from the ocean floor leads to a displacement of water and sea level rises. When a part of the ocean becomes deeper due to downward displacement of the ocean floor due to earth movements, the volume of the ocean basin increases and sea level will fall.

Local changes and world-wide changes in sea level get superimposed over one another and therefore not change in sea level shows wide variations. For example, the west coast of India between Bombay aud Goa has the appearance of a shoreline of submergence, while the Kerala coast resembles a shoreline of emergence. Sea level changes are of great significance to the people living along the coast.

EXERCISE — 6

Short Answer Questions :

1. Why is the earth called the 'watery planet'?
2. What are multipurpose projects?
3. What is meant by the hydrological cycle?
4. Name the processes involved in the hydrological cycle.
5. Distinguish between continental shelf and continental slope.
6. How is the composition of sea water different from that of river water?
7. What factors affect the salinity of sea water?
8. How are cool currents produced?
9. What causes world wide changes in sea level?
10. How do earth movements affect changes in sea level?

Essay Questions :

1. Describe the importance of water to man.
2. Give a clear account of the hydrological cycle.
3. Describe the main features of the Atlantic ocean.
4. Describe the general pattern of surface currents in the oceans.
5. Give an account of the importance of ocean currents.

7. Hydrosphere—II

We have learnt in the last chapter that the Hydrosphere comprises water in the oceans, water on the land and below the land and water in the atmosphere. Though water is moving between these three realms — oceans, land and air — each realm is dealt with separately for the sake of clarity. The last chapter dealt with a study of the oceans and this chapter relates to water on the land and below the land. Water in the air will be described in the chpater on the "Restless Atmosphere"

Water on the Land

Water is present on the land in the form of surface flow such as rivers or glaciers or as surface storage in the form of lakes or ice sheets. Water on the land is primarily derived from precipitation from the atmosphere. Snow fall results in the formation of snow fields and ice sheets from which glaciers may move down extremely slowly. Rainfall on the other hand results in rapid flow of water down the slope of the land in the form of streams and rivers. Running water may fill up depressions along its path to form lakes.

River Systems

Rivers originate when there is sufficient water to flow down the slope of the land. Most of the water flowing in rivers is derived from rainfall, though it may be supplemented by water from springs and melting of ice sheets and glaciers. The water which flows on the surface of the land is known as **run-off**. The quantity of run-off in a given area depends not only on the rainfall received but also on other factors. A part of the rainfall gets lost by **evaporation**, another part is lost by **seepage** below the ground and some quantity is lost by **transpiration** by plants.

The loss due to evaporation is related to the temperature of the atmosphere, cloudiness and winds. Evaporation is a maximum in tropical deserts which experience high

temperature, clear skies and strong winds. In the equatorial regions, evaporation is less owing to cloudiness and absence of strong winds. Evaporation is least in the cold polar regions.

The quantity of water lost by seepage below the ground is related to the nature of rocks and soils on the surface of the land. Water seeps through pore spaces and joints in the rocks. Sandstone has a large volume of pore spaces between particles of sand and such rocks permit seepage of large quantities of water. Crystalline rocks like granite do not have pore spaces between crystals. Such rocks permit seepage of water through joints and fissures present in them. Rocks which permit ready seepage of water through them are known as permeable rocks. Impermeable rocks are those which do not permit ready seepage of water. Clay is an example of an impermeable rock.

Plants absorb water through their roots, pass it through stem and branches and finally evaporate it through their leaves. Thus large quantities of water are drawn by plants from the soil layer and get evaporated through the leaves to the atmosphere. This process of loss of water through the plants is known as transpiration. The quantity of water lost by transpiration in an area will depend on the type of vegetation in the area and its density. Transpiration is a maximum in forests, moderate in grasslands and a minimum in deserts.

Thus the quantity of water flowing in streams in an area is thus determined by the interplay of several factors. The positive factors are precipitation, addition of melt water from glaciers and water added from springs. The negative factors are the losses due to evaporation, seepage and transpiration. The quantity of run-off in a river basin thus depends on the climatic conditions, the type of rocks and soils and the type and density of vegetation. The topography is another important factor as run-off is related to the slope of the land. Water runs off rapidly on steep slopes while run-off is slow and not well defined on gentle slopes.

River Regimes

The volume of water flowing in a river shows wide fluctuation which are seasonal and annual. Perennial rivers are those in which there is a flow of water through out the year. Non-perennial rivers are those which are dry during a part of the year. These rivers dry up because rainfall is extremely seasonal and it is not supplemented by springs or melting of ice. Palar river in Tamilnadu is an example of a non-perennial river. Cauvery river is a perennial river because it has a large river basin with its tributaries receiving rainfall in different seasons. The rivers flowing from the Himalayas are perennial because rainfall is supplemented by water derived from melting of ice and snow.

The seasonal variations in the volume of water in a river is known as its **regime**. The regime of a river is related to the climatic conditions in the basin of the river. In equatorial regions, there is no dry season and the distribution of rainfall shows two periods of maxima coinciding with the equinoxes, i. e., March and September. The regime of rivers in equatorial regions shows two peaks coinciding with that of rainfall distribution. In tropical and subtropical regions with seasonal rainfall, the regime of rivers shows a single peak following the period of maximum rainfall. In the dry season, such rivers may dry up completely unless it is fed from springs or meeting of ice. In the middle and high latitudes, rivers may get frozen in winter and there will be no flow of water. With the beginning of spring, melting takes place and there is maximum flow.

A careful study of the regime of a river and its various tributaries is necessary in order to make the best use of the river system. Rivers provide the main source of fresh water to meet the requirements of man. These requirements, include irrigation by canals, hydro-electric power development, domestic and industrial needs and navigation in some cases. An integrated planning of river basins is necessary especially in the case of inter-state rivers in India. Multipurpose River

Valley projects like that of the Damodar Valley in Bihar and West Bengal have been undertaken in order to make the best use of the flow of water available in the river system.

Lakes

Lakes are hollows or basins containing water. Lakes vary in size, depth and quality of water. If we examine a world map, large lakes such as the Caspian sea, the Great lakes of North America and the lakes of East Africa stand out prominently. The Caspian sea is an inland sea covering an area of 450,000 sq. km. Small lakes and ponds may occupy only a few square metres. While most of the lakes are shallow, lakes occupying structural basins are exceptionally deep. Lake Baikal in Siberia has a depth of about 1500 metres. Lakes drained by rivers contain fresh water. For example, the Great lakes of North America contain fresh water as the lakes are drained by the St. Lawrence river. Inland seas and lakes without any outlet contain saline water. The Caspian sea, Aral sea and Dead sea are examples of lakes containing saline water. The Sambhar lake in Rajasthan is also a salt water lake. Such lakes are sources of salt.

The lakes interact with the physical environment actively. Water evaporates from the surface of the lake and adds water vapour to the atmosphere. Water also seeps below the floor of the lake and adds to the ground water storage. The volume of water in the lake is related to a number of factors. Water is added to a lake by rainfall over the lake surface and also by streams which may enter the lake. Some lakes may also get water from melting of ice on the mountain slopes or from springs. Water from lake is lost by direct evaporation from the surface, seepage into the ground below the floor of the lake and also through streams flowing out of the lake. In such cases the level of the outlet determines the quantity of water which may be drained out of the lake. Inland lakes experience large fluctuations in volume of water. For example, Lake Chad in Africa is a shallow inland lake whose area fluctuates between 10,000 and 50.000 sq. km.

Lakes are usually classified on the basis of the origin of the depressions on the earth's surface. Large lakes occupy

structural basins or depressions on the earth's surface. The Caspian sea occupies such a structural basin. Lakes occupy floors of rift valleys produced by faulting. The Great Rift Valley of East Africa contains narrow and deep lakes such as Lake Tanganiyaka, Lake Malawi, Lake Rudolf and smaller ones. Lakes in Kashmir and Kumaon region of the Himalayas occupy depressions surrounded by mountain ranges. Lake Baikal in Siberia occupies a basin produced by faulting.

Lakes may also be formed owing to volcanic activity. The crater or depression in the summit of the volcano may be occupied by a lake. Such lakes are called **Crater Lakes**. The best example is the Crater lake in Oregon state of the United States. Lonar lake in Maharashtra state is also considered as a crater lake. Lava flows from volcanoes may dam river courses to form lakes.

A number of lakes of varying sizes are formed by the erosive and depositional activities of gradational processes. River action leads to the formation of ox-bow lakes which occupy abandoned river channels. A number of such ox-bow lakes occur in the lower course of the Ganges river in Bengal. The formation of sand bars along the edge of the delta may lead to blocking the river channels to form lakes called **Delta Lakes.** Kolleru lake in Andhra Pradesh may be considered as a delta lake as it is located between the deltas of the Krishna and Godavari rivers.

Glacial action leads to the formation of lakes both due to erosion and deposition. The movement of continental glaciers leads to the formation of rock basins of varying sizes due to erosion. After the glaciers melt away, these basins contain lakes. Deposits laid down by glacier as in the form of moraines produce a highly uneven surface with a number of depressions. Such depressions form lakes. Thus the large number of lakes in Canada and Scandinavia are of glacial origin resulting from erosion as well as deposition. Continental glaciers disturb the surface drainage and lakes

are formed along the margins of glaciers. The Great lakes of North America are of glacial origin. Glaciation of mountain regions leads to the formation of basins in cirques and U-shaped valleys. After glaciation comes to an end these basins form Cirque lakes and **Finger Lakes** respectively. Damming of river valleys by glacial deposits may also lead to the formation of lakes.

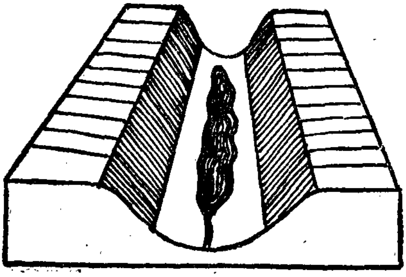


Fig. 7.1

Finger Lake

[Note that the lake is located in a U-shaped valley.]

In desert regions, rain water stagnates in small basins to form lakes called **Playa lakes.** Such lakes dry up after a few days leaving a layer of salt on the surface. Wind action removing sand particles from the surface of deserts may lead to the formation of large basins such as the Qattara depression in Egypt. Such basins may form salt lakes or swamps.

Lakes may also be formed by the action of waves along the coast. The formation of sand bars along the coast prevents the drainage of water from the land leading to stagnation of water behind the bar. This forms shallow lagoons and lakes along the coast. The Vembanad lake near Cochin and the backwaters of Kerala are of such origin. The Pulicat lake and Chilka lake along the east coast of India are also the result of wave action.

In limestone regions, lakes are formed in depressins caused by solution of limestone rock. Such lakes are called **karst lakes** and they dry up quickly as water seeps down through the floor of the lake. Landslides and other forms of sudden movement of rocks and soils along steep slopes of mountain regions may block river valleys to form lakes.

The construction of dams across river courses has produced many **man-made lakes**. The Bhakra dam on the Sutlej is the highest gravity dam in the world. It impounds 780,000 hectare metres of water. The Hoover dam across the Colorado river in the United States and the Kariba dam across the Zambezi river in Africa have produced large man-made lakes. Such lakes help in flood control, irrigation and power generation. Mettur dam across the Cauvery river in Tamilnadu has extended irrigation facilities in the delta by regulating the flow of water.

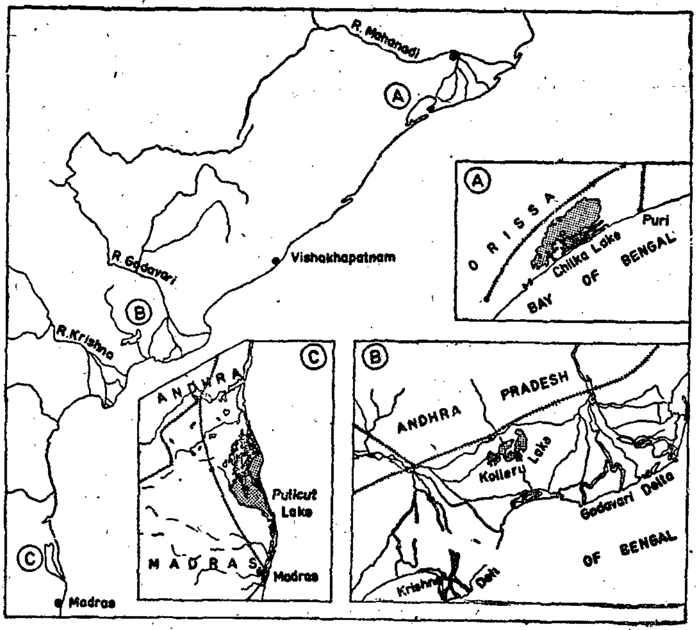


Fig. 7.2

Lakes along the east coast of India

Lakes are generally ephemeral or temporary features of the landscape, though lakes in structural basins like rift valleys are relatively more permanent. Lakes usually get filled up by deposition of sediments brought down by rivers entering the lake. Lakes may be drained away by lowering of the outlet owing to

erosion by river flowing out of the lake. Climatic change from humid to arid conditions may lead to increased evaporation leading to drying up of the lake in course of time. A general lowering of water table may lead to a gradual fall in level of the lake ultimately leading to its drying up.

Old lake floors contain deposits laid down in the former lakes. As the deposits are laid in water, the particles are arranged according to their size. Coarse particles get deposited along the margins and finer particlcs like clay are deposited towards the centre. Deposits laid down in lakes are known as **lacustrine deposits.** The Kerewas in the Kashmir valley are considered to be deposits laid down in an old lake.

Lakes are of great significance in several respects. Lakes along the courses of rivers help in regulating the flow of water and thus prevent floods. Large lakes such as the Great lakes of North America modify the climate of the adjoining land masses The Great Lakes also serve as inland waterways for bulky commodities like iron or and coal. Lakes add to the scenic beauty of the landscape and encourage recreation such as fishing and boating. Salt lakes provide a variety of salts by simple evaporation of water in shallow pans.

Sub-surface Water

We have seen earlier that a part of the rainfall seeps below the ground and the quantity of seepage depends on the

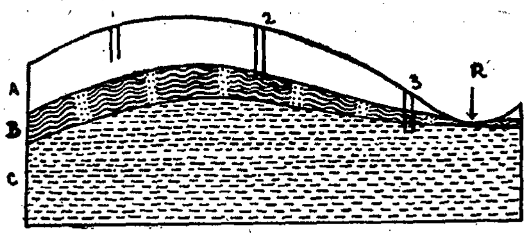


Fig 7.3

Water Table

Water Table is the line seperating B and C Zones.

nature of rocks and soils. Seepage of water through the pore spaces and joints in the rocks does not continue beyond a

depth of a few hundred metres. Normally there is no trace of water in the rocks even at a depth of 1000 metres. The seepage of water gets retarded as pressure of the overlying rocks closes the pore spaces and joints. Thus there is a lower limit to the seepage of water below the ground. As more and more water seeps down, it accumulates above this limit and saturates all the pore spaces in the rocks. The upper surface of the zone of asturation of water is known as the **water table.**

Three different zones may be distinguished on the basis of the availability of sub-surface water. Immediately below the surface of the land is the **zone of aeration,** through which water percolates readily. In this zone, the pore spaces and joints in the rocks are filled with air. This zone is free from ground water. Below this is a **zone of temporary saturation,** in which pore spaces are filled with water during the rainy season only. This is because water table rises upto this level in the rainy season. As the water table falls during the dry season, the zone of temporary saturation is relatively dry. Below the zone of temporary saturation is the **zone of perma -nent saturation,** in which all the pore spaces are permanently saturated with water.

The level of the water table rises during the rainy season and falls during the dry season. Factors other than the seasonal distribution of rainfall also influence the level of the water table. Topography is an important factor. The profile of the water table is in accordance with the general profile of the land. Water table is deeper in upland tracts than in valleys or lowlands. Water bodies like streams, lakes and ponds affect the water table. As these surface drainage features permit ready seepage of water, water table rises in the area around these water bodies. In areas of tank irrigation in Tamilnadu, the level of water in the tanks controls the level of ground water. When tanks are full, water table is high and wells may contain much water. When water level in tanks falls, water table sinks and level of water in wells also goes down.

Water table may fall as a result of excessive utilisation of ground water by pumping from wells. The rate at which water is pumped out of the zone of saturation is greater than the rate at which water seeps below the ground. A gradual fall in the level of the water table leads to drying up of shallow wells. Such canditions are found in parts of Coimbatore district in Tamilnadu.

The level of water table is also affected by the nature of rocks in the area and their structure or arrangement. In regions of sedimentary rocks, the permeability is a maximum in rocks like sandstone. Such rocks which permit ready passage of water through them are called **acquifers.** Clay is an example of an impermeable rock or **acquiclude.** When these rocks are arranged alternatingly, impermeable rocks prevent seepage of water and therefore water accumulates in the acquifers above them. When there are several permeable beds with impermeable beds between them, there may be more than one water table in the region.

Springs

Springs are places at which ground water reappears at the surface. Springs occur at places where the water table intersects the surface. Water will flow out of a spring only as long as there is sufficient pressure in the water table. Springs are commonly found at the line of contact between permeable and impermeable rocks. As the impermeable rocks do not permit seepage of water downwards, water moves horizontally in the zone of saturation formed in permeable rocks and escapes through springs at the junction between permeable and impermeable rocks. Springs also occur at places where joints or fissures are exposed on the surface.

Springs are commonly found along the sides of river valleys because the formation of the valley by erosion has exposed the water table along the sides of the valley. Springs may be seen along the line of a fault, when the fault has led to the displacepment of ermeable and impermeable beds. The flow of water from springs is subject to changes in the level

of the water table. While some springs are perennial, others are seasonal.

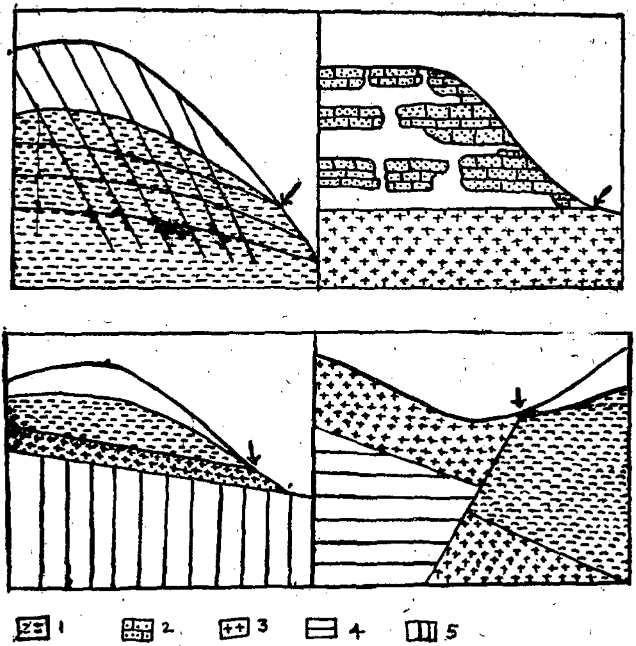


Fig. 7.4

Springs

Arrow indicates springs

1. Zone of saturation 2. Limestone rock (Note caves formed by solution) 3. Impermeable rocks 4. and 5. Other rocks.

Wells

Wells are dug to tap the underground water. Wells are used to supplement surface water supplied from rivers and lakes. Shallow wells dry up in summer as they tap only the zone of temporary saturation. Deep wells which tap the zone of permanent saturation may contain water throughout the year. Water level in wells rises and falls in response to changes in the level of the water table. Water level in wells is also affected by the rate at which water is pumped out

from the wells. The use of electric pumpsets has rapidly increased the rate at which water is pumped out, leading to a lowering of water table.

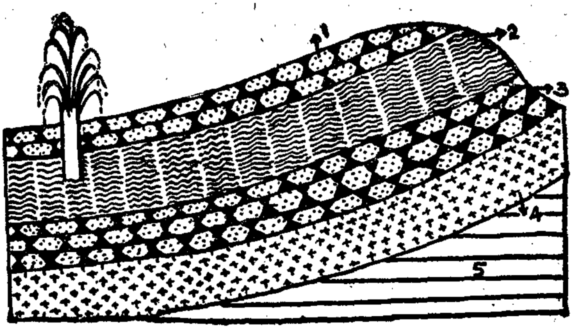


Fig 7.5

Artesian Wells

1. and 3. Impermeable rocks
2. Permeable rocks — Zone of Saturation
4. and 5. Other rocks

Artesian wells are those in which water rises to the surface of its own accord as in a fountain. There is no need to lift water from depths as in an ordinary well. Water rises to the surface because of high pressure in the zone of saturation below the surface. Such conditions prevail when a thick permeable rock lies between two impermeable rocks at the top and bottom. The permeable rock should be exposed on the surface at a higher level so that rain water seeps through and forms a zone of saturation in the permeable rock. As impermeable rocks occur above and below the zone of saturation, considerable pressure is built up in the ground water. When a well is dug to reach the water table, water gushes out as in a fountain. Another condition is that the level of the well must be lower than that at which the permeable rock outcrops on the surface. Artesian wells are found in the Great Artesian basin which covers parts of New South Wales and Queensland. Artesian wells occur in Pondicherry and South Arcot District.

Hot springs and **geysers** are known to occur in volcanic regions and regions of crustal instability. Hot springs derive water from great depths at which rocks are at a high temperature, Temperature increases at an average rate of 1°C per 32 metres of depth below the earth's surface, Water rises to the surface through deep fissures. Geysers are fountains of hot water and steam erupted at intervals of time. Hot springs and geysers are found in Iceland, western United States and New Zealand. Hot springs are known to exist in parts of the Himalayan region.

Ground water acts as an agent of denudation in regions of soluble rocks such as limestone. The movement of ground water through joints and fissures leads to solution of the rock and this produces caves and caverns. Limestone regions lack surface drainage as water seeps down readily through shallow depressions called sink holes. The surface of the limestone region may have such depressions of varying sizes.

Caves and caverns are well developed in regions where thick limestone bed is exposed on the surface. The mammoth Cave region of Kentucky in the United States has caverns extending to a total length of about 50 kilometres. Limestone region in Bastar district of Madhya Pradesh has well developed caves.

Water which seeps through the limestone region causing a variety of landforms through solution, reappears at the surface at the base of the limestone bed. Portions of the limestone bed not yet completely dissolved may remain as isolated hills.

EXERCISE–7

Short Answer Questions:

1. What factors control evaporation in a region ?
2. Distinguish between permeable and impermeable rocks.
3. What is transpiration ?
4. Why are some rivers non-perennial ?

5. What is the importance of a multipurpose project ?
6. Why is it that some lakes contain saline water while others contain fresh water ?
7. How do lakes interact with the physical environment ?
8. Why are lakes considered as temporary features of landscape ?
9. What are lacustrine deposits ?
10. What is meant by water table ?
11. How are springs caused ?
12. What are artesian wells ?

Essay Questions:

1. Describe the various factors which cause variations in the volume of water in a river.
2. Attempt a classification of lakes. Give suitable examples.
3. Describe the factors which influence the level of water table in an area.
4. Describe the work of ground water as an agent of denudation.